Lake Lemon T by 2000 Feasibility Study

—Final—

Submitted to:
Bloomington Board of Parks and Recreation
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LAKE LEMON ENHANCEMENT STUDY

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SUMMARY

Lake Lemon is a 583 hectare (1,440 acre) reservoir located in northeastern Monroe County, Indiana. The reservoir is shallow, with a maximum depth of 8.5 meters (28 feet) and a mean depth of 2.9 meters (9.7 feet). Lake Lemon was constructed in 1953 for flood control, recreation, and as a drinking water supply for the City of Bloomington. The City of Bloomington owns the reservoir but does not use it for drinking water at this time. However, it retains the status of a back-up drinking water supply for the City.

Lake Lemon has a large (182 km^2/70 mi^2), mostly forested drainage basin characterized by steep topography. About 80% of the drainage basin is drained by Beanblossom Creek and its tributaries. Lake Lemon's hydraulic flushing rate was calculated as 5 times/year for the 1982 water year. Turbidity in Lake Lemon is high following storm events. Most of the suspended material settles out in the eastern end of the lake where sedimentation is a problem. Little sedimentation has occurred in the lake's western end.

Lake Lemon has a largely meromictic circulatory patter. The only stratification observed occurred in the original streambed of Beanblossom Creek which accounts for only 5% of the total lake volume. Dissolved oxygen was limiting in these bottom waters in late summer. The nutrient budget for Lake Lemon suggests that there is little net deposition of phosphorus in the lake and, to the contrary, there may be some export of phosphorus from the lake. Most phosphorus enters the lake in particulate form from Beanblossom Creek. On-site septic systems were judged to be a minor source of phosphorus input; however, two local areas do receive significant inputs of septic leachate.

Algal biomass in Lake Lemon is relatively low. The major water quality problem in Lake Lemon is the dense growth of the aquatic macrophyte Myriophyllum spicatum (Erasion water milfoil) which was found in nearly all waters of the lake having a depth between 0.75 and 3 meters (2.5 - 10 feet). The dense growths restrict boating and swimming activities.

Watershed modeling using the Agricultural Nonpoint Source Model (AGNPS) identified areas having higher amounts of runoff, sediment loss and nutrient loss. For the most part, these areas tend to be in the northeastern part of the watershed where most of the agricultural activity is located. Streambank erosion is a serious problem in lower Beanblossom Creek where peak discharges from the large watershed erode the alluvial silt of the floodplain. Nearly all permanent streams in the watershed suffer from some degree of streambank erosion.

Recommendations for enhancing the water quality of Lake Lemon include implementation of the following:

1. Agricultural best management practices.

2. Streambank erosion controls.

3. Lakeshore erosion controls.
4. Forestry best management practices.
5. Septic system monitoring, maintenance and repair.
6. Construction of sedimentation basins.
7. Wetlands enhancement.
8. Continued macrophyte harvesting.
9. Outlet repairs and improvements to facilitate winter drawdown.

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ACKNOWLEDGEMENTS

Funding for this study was made available by a grant to the Bloomington Board of Parks and Recreation from the T by 2000 Lake Enhancement Program of the Indiana Department of Natural Resources, Division of Soil Conservation and by local contributions.

We are grateful to Mark Young, Lake Lemon Manager, for assessing shoreline erosion and assisting us with our watershed investigations. The assistance of Joe Peden of the Monroe County SCS and Jim Blank of the Brown County SCS was invaluable in completing the AGNPS modeling.

CHAPTER 1: INTRODUCTION

Lake Lemon was constructed by the City of Bloomington in 1953, in a hilly, heavily wooded drainage basin, by impounding Beanblossom Creek. The lake is used currently for flood control, low-flow augmentation, recreation, and as a supplemental drinking water supply for the City of Bloomington.

For many years Lake Lemon has provided valuable recreational opportunities for many residents of south central Indiana. Boating, sailing, fishing, and swimming are all popular activities. However, the lake water quality has deteriorated sufficiently over time to cause concern to the local citizens and city officials. Today, the lake suffers from decreased water clarity, sedimentation, shoreline erosion, and dense growths of nuisance aquatic macrophytes. These conditions have impaired recreational uses of Lake Lemon.

This study is part of a continuing effort to improve water quality conditions within Lake Lemon. Efforts to date include:

1. A comprehensive program to annually treat the dense aquatic macrophytes with chemical herbicides, begun in 1979.

2. A 1981 U.S. EPA Phase I Diagnostic Feasibility Study of Lake Lemon (Zogorski et al., 1986).

3. Purchase of a mechanical weed harvester in 1985, as recommended in the Phase I study, and initiation of a comprehensive harvesting program.

4. Shoreline stabilization work at the City park on Riddle Point.

5. Local efforts to form a Conservancy District around Lake Lemon to coordinate lake management efforts and to establish a source of lake management funds.

Recommendations contained in the completed Phase I Study could not be implemented fully due to lack of funds at both the local and federal levels. The reauthorization of the federal Clean Lakes Program in 1987, along with the creation of the Lake Enhancement Program within the Indiana Department of Natural Resources Division of Soil Conservation in 1987, provided the long-awaited opportunity for funding an implementation program at Lake Lemon.

The purpose of the present study is to satisfy additional requirements of the U.S. EPA Clean Lakes Program and to complete the feasibility study requirements of the Lake Enhancement Program. With the successful completion of these requirements, Lake Lemon will become eligible for design and implementation grants from both programs.

While portions of the original Phase I report entitled, "Lake Lemon Diagnostic/Feasibility Study" (Zogorski et al., 1986) are duplicated in the present report to provide continuity, the reader is referred to the Phase I Study for more detail. Copies of the 1986 report are available and will be included with each copy of the present report.

CHAPTER 2: LAKE SETTING

2.1 LOCATION

Lake Lemon is located on the boundary between Monroe and Brown Counties, approximately nine miles northeast of Bloomington, Indiana (Figure 2-1). It lies primarily within sections 27, 28, 33, 34, 35, and 36, T10N, R1E; and section 31, T10N, R2E. Lake Lemon is bounded on the south by South Shore Drive, on the east by state highway 45, and on the north by North Shore Drive (Figure 2-2).

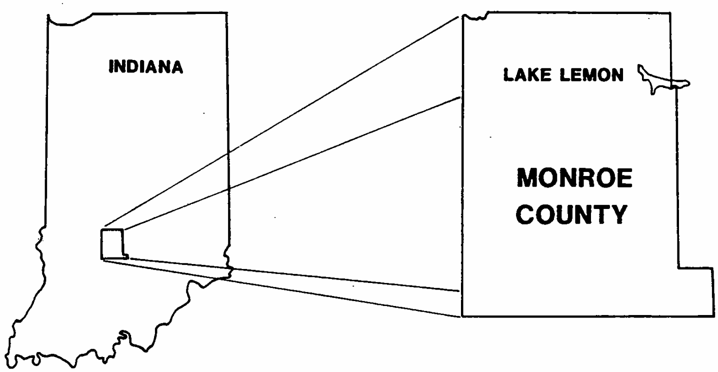


Figure 2-1. Location map.

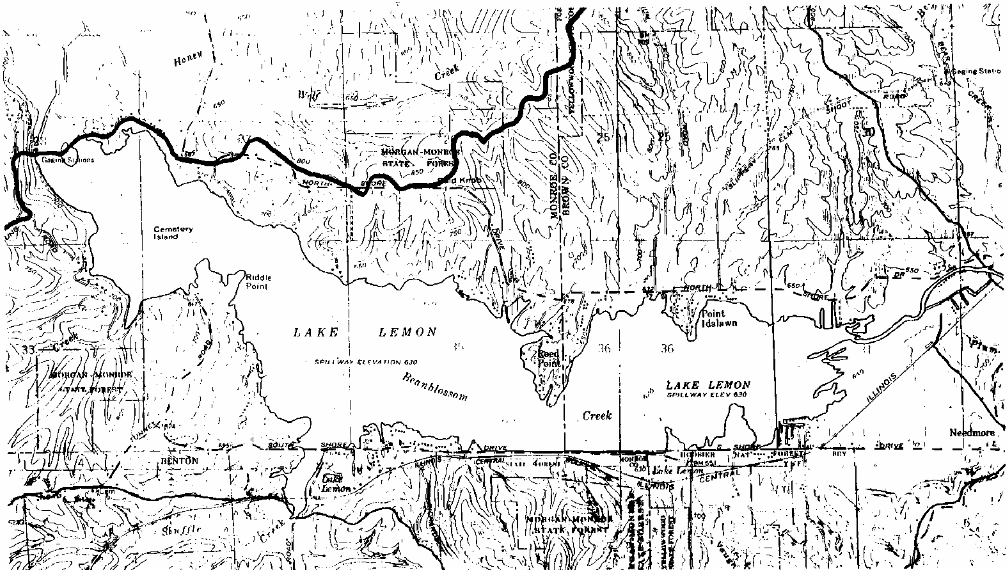


Figure 2-2. Topographic map of Lake Lemon. Drainage basin boundaries are indicated. Water sample location shown by an asterisk (*).

2.2 LAKE MORPHOMETRY

Lake Lemon has an elongated shape running west to east that is divided roughly into three lobes by two peninsulas known as Riddle Point and Reed Point. Morphometric parameters for Lake Lemon are presented in Table 2-1 and Figure 2-3.

TABLE 2-1. LAKE LEMON MORPHOMETRY

Maximum Length	6.5 km (4.0 miles)
Maximum Width	1.5 km (0.9 miles)
Surface Area	583 hectares (1,440 acres)
Volume	17,100,000 cubic meters (13,900 acre-feet)
Maximum Depth	8.15 meters (28 feet)
Mean Depth	2.9 meters (9.7 feet)
Shoreline	24 km (14.9 miles)

2.3 DRAINAGE BASIN SIZE AND CHARACTERISTICS

Lake Lemon drains a hilly and predominantly wooded area of approximately 182 km^2 (18,200 ha) or 70.2 mi^2 (44,900 acres) in size, including the lake area (Figure 2-4). This results in a rather large drainage area to lake area ratio of 31:1. Of the total drainage basin, 88% (160 km^2) lies in Brown County, 12% (21 km^2) in Monroe County, and < 1% (0.5 km^2) in Johnson County.

There are no large towns in the Lake Lemon watershed, only small villages (Trevlac, Helmsburg, Beanblossom, Fruitdale, and Spearsville).

Lake Lemon receives runoff primarily from Beanblossom Creek and its tributaries, which drain 81 percent of the watershed. Supplementary runoff is received from several small streams and directly from the immediately surrounding forested ridges. Table 2-2 lists the drainage areas of the individual basins within Lake Lemon's watershed.

The only outlet from Lake Lemon is Beanblossom Creek and flow from the lake is controlled. Water is discharged over the spillway (elevation 630 MSL) when the lake level is high or can be released through an outlet structure that draws water from the lake's bottom waters.

2.4 GEOLOGY

Lake Lemon and its drainage basin lie in the Norman Upland physiographic province, a severely dissected plain. Long narrow ridges with steep slopes descend into V-shaped ravines or from narrow valleys with nearly flat bottoms (Schneider 1966). Topography is most rugged along the southern border of the watershed, and only slightly less rugged in the northwestern quadrant. Elevations range from 192 meters (630 ft) above MSL (elevation of the spillway of Lake Lemon) to 315 meters (1033 ft) at Bearwallow Hill (4 km ESE of the Village of Beanblossom). Ridgetops of 260-275 meters are common, whereas all

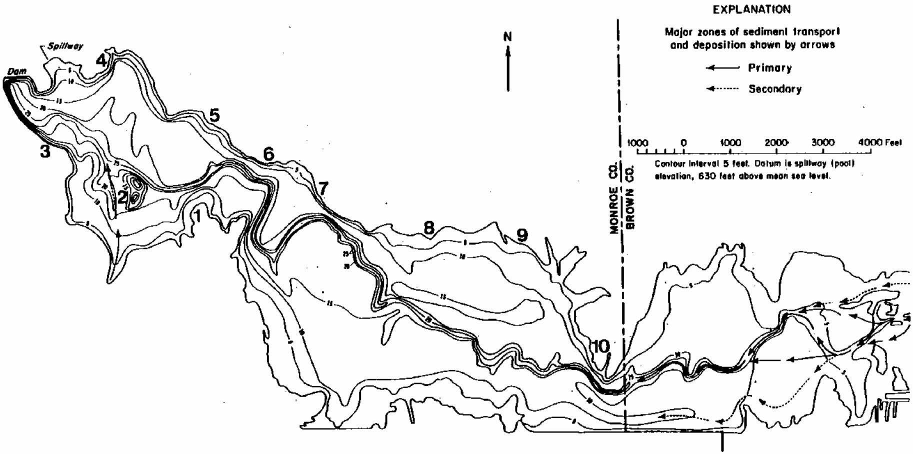


Figure 2-3. Bathymetric map (Source: Hartke and Hill, 1974).

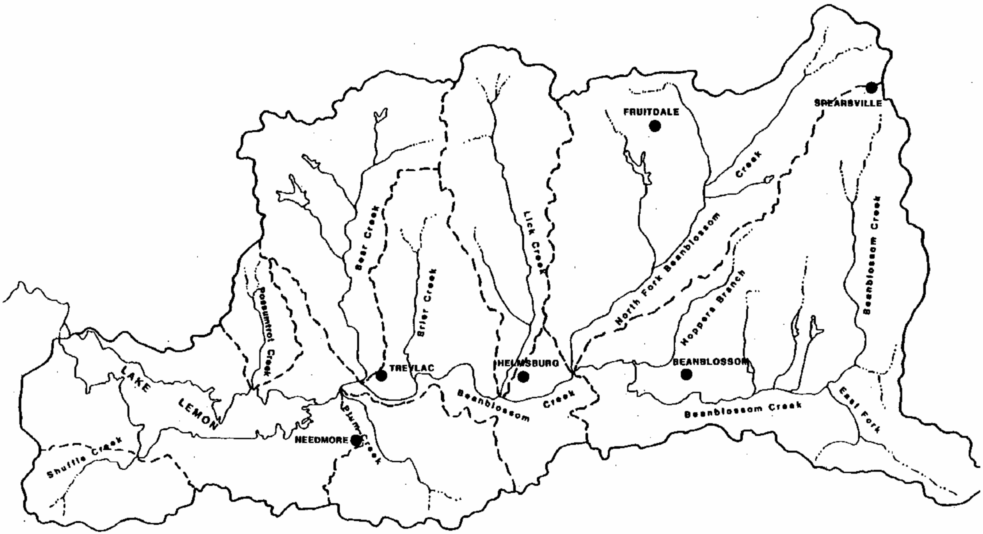


Figure 2-4. Lake Lemon drainage basin.

TABLE 2-2. SUB-BASIN DRAINAGE AREAS WITHIN LAKE LEMON'S WATERSHED

Sub-Basin	Area km^2	mi^2
North Fork Beanblossom Creek	33.4	(12.9)
Lick Creek	16.3	(6.3)
Brier Creek	7.3	(2.8)
Bear Creek	19.7	(7.6)
Plum Creek	11.1	(4.3)
Slippery Elm Shoot Creek	1.6	(0.6)
Beanblossom Mainstem	58.8	(22.7)
Total Beanblossom Creek	148.1	(57.2)
Possumtrot Creek	3.9	(1.5)
Rapid Creek	2.1	(0.8)
Shuffle Creek	6.7	(2.6)
Other drainage	15.0	(5.8)
Lake Lemon	6.0	(2.3)
TOTAL LAKE LEMON WATERSHED	181.8	(70.2)

major bottomlands lie below 230 meters, and most below 220 meters. Hence, local topographic variations of 30-60 meters are common throughout the watershed (see the Beanblossom, Belmont, Hindustan, Morgantown, Nashville, and Unionville 7.5 minute U.S. Geological Survey quadrangle maps).

2.5 SOILS

2.5.1 Soils of the Watershed

Published modern soil surveys are available for Monroe County (Thomas, 1981), Brown County (Noble et al., 190), and Johnson County (Sturm, 1979). Over 30 soil mapping units (Monroe Co., 13 units; Johnson Co., 6; Brown Co., 20) are represented throughout the watershed. Designations of soil mapping units differ slightly from one county to the next. Most important, a few mapping units, particularly those representing complexes of two or more soils, may change names at county lines. These name changes result from disagreements between descriptions of the soils by soil mappers.

Nearly all of the soils of the watershed are silt loams; a few are loams or channery loams. They originate from five types of parental materials: bedrock residuum, loess, glacial till, glacial outwash, and recent alluvium (Thomas, 1981). An areal breakdown for the watershed gives bedrock residuum and loess-covered bedrock, 75% of the area; glacial till, 8%; terrace soils on glacial outwash, 3%; and recent alluvial soils, 14%.

Soils throughout the watershed generally have low permeability (0.6-2.0 inches/hour), that can be very low (0.06 inches/hour) where fragipans (e.g., in Bartle, Hosmer, Pekin, and Tilsit soils) or clay beds (e.g., in Peoga soils) are present. The seasonal high water table lies below two meters of the land surface in most soils. Those with conditions favoring a perched water table include Bartle, Bedford, Hosmer, and Tilsit soils. Apparent high water tables at depths less than two meters below the land surface occur in Burnside, Muren, Pekin, Peoga, Steff, and Standal soils. Burnside, Haymond, Steff, and Stendal soils are subject to flash flooding (Sturm 1979; Thomas 1981).

Much of the land within Lake Lemon's watershed has the potential to be classified as highly erodible land (HEL). However, because most of the land use is in forest, very little land (<5%) can be classified as HEL (Joe Peden, pers. comm.). The amount and location of HEL varies annually with cultivation practices. Most of the cultivated lands are not highly erodible since they are on the flatter ridge tops and along valley bottoms. Conversion of forest land to cultivated crop land would increase the amount of HEL in the watershed.

2.5.2 Near Shore Soils

In general, steep slopes, low percolation capacity, wetness or flooding render the near shore soils unsuitable for use as septic fields. Only 5% of the shoreline is moderately suitable for development of septic systems and this land presently includes only 9% of the housing units in the Lake Lemon watershed (Tables 2-3 and 2-4). Slow percolation rates suggest that groundwater seepage into the lake may be slight under most conditions. However, surface runoff, especially during storms, can be significant, and stream side flooding becomes a potential problem along Beanblossom Creek.

2.6 LAND USE

The following percentages of land use classes occur within Lake Lemon's drainage basin:

Forest	77%
Agriculture (including pasture)	19%
Residential	2%
Ponds	1%
Wetlands	0.6%
Campgrounds	0.3%

The immediate shoreline of Lake Lemon has patchy developments of permanent and summer residences interpersed with undeveloped shoreline (see Figure 2-2). The density of houses ranges from acre-sized lots with houses set well back form the water to one-eighth acre lots with houses next to the water (e.g., adjacent to the canals at the southeastern end of the lake).

The dominant land use away from the lake is forest land. However, timber harvesting on these lands is highly variable. We did not observe significant areas of active timber harvesting during the study. Agriculture occurs predominantly in the valleys and also on ridge tops. Corn is the major crop grown. Land use percentages by sub-basin are presented in Table 2-5 and Figure 2-5. These data were measured from 1980 aerial black & white photographs of the watershed and were confirmed by spot ground truthing, comparison with USGS 7.5 minute topographic maps, and comparison with the current USDA soil surveys.

TABLE 2-3. SOILS[1] AND RESIDENTIAL LAND USE ALONG THE MONROE COUNTY SHORELINE OF LAKE LEMON

Map Symbol[1]	Name	Physiography[1]	Shoreline Length (mi)[2]	Number of houses: Quad est. (1961-1966)[3]	Number of houses: Shoreline Count (1982)[4]	Hazard for septic tank adsorption fields[1]
Ba	Bartle silt loam	terraces	0.75	3	1	severe/wet/low perc
Bkf	Berks-Weikert Complex, 29-75% slopes	steep hillsides	2.57	7	38	severe/depth/slope
Ekf	Elkinsville silt loam, 20-40% slopes	lower slopes	5.13	47	77	severe/slope
Hd	Haymond silt loam	well drained bottoms	0.25	0	0	severe/floods
PeA	Pekin silt loam, 0-2% slopes	low terraces	1.08	32	31	severe/wet/low perc
PeB	Pekin silt loam, 2-6% slopes	low terraces	0.75	1	2	severe/wet/low perc
Wmc	Wellston-Gilpin silt loams 6-20% slopes	ridge tops	0.55	0	12	moderate/depth/slope/ low perc
TOTAL			10.48	90	161	

[1]Source: Thomas et al. 1981
[2]Determined by wheel gauge on soil survey maps
[3]Counted from U.S.G.S. quadrangles
[4]Survey, this project

TABLE 2-4. SOILS[1] AND RESIDENTIAL LAND USE ALONG THE BROWN COUNTY SHORELINE OF LAKE LEMON

Location Map Symbol[1]	Name	Physiography[1]	Shoreline Length (mi)[2]	Number of houses: Quad est. (1961-1966)[3]	Number of houses: Shoreline Count (1982)[4]	Hazard for septic tank absorption fields[1]
Lakeshore						
Bgf	Berks, Gilpin Variant, 20-50% slopes	steep hillsides	0.04	2	4	severe/slope/depth
Bu	Burnside (Beanblossom) silt loam	bottoms	0.40	3	6	severe/floods/wet
Cdf	Chetwynd loam, 12-18% slopes	terraces	0.34	10	17	moderate/slope
DuA	Dubois silt loam, 0-6% slopes	terrace	0.51	0	0	severe/wet/low perc
HaB_2	Haubstadt silt loam, 0-18% slopes	terrace	0.46	23	60	severe/wet/low perc
OtC_2	Otwell silt loam, 6-12% slopes	terraces	0.79	8	32	severe/low perc
St	Stendal silt loam	bottom	0.43	0	0	severe/floods/wet
Other	Unnamed	wetland	1.42	0	0	severe/wet/floods
TOTAL			4.38	46	119	
Beanblossom Channel						
Cdf	Chetwynd loam, 12-18%	terraces	0	0	1	moderate/slope
Hc	Haymond silt loam	bottom	2.24	43	64	severe/floods
Sf	Steff silt loam	bottom	0.35	2	2	severe/floods/wet
St	Stendal silt loam	bottom	0.33	0	0	severe/floods/wet
Other	Unnamed	wetland	0.23	0	0	severe/wet/floods
TOTAL			3.15	45	67	
GRAND TOTAL			7.53	181	347	

[1]Brown County Soil Conservation Service, unpublished data

[2]Determined by wheel gauge on preliminary soil survey data maps

[3]Counted from U.S.G.S. quadrangles

[4]Survey, this project

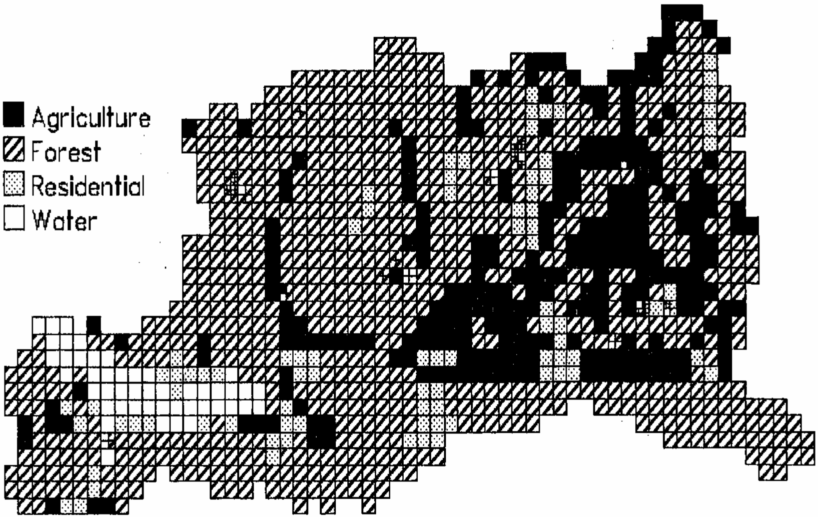


Figure 2-5. Generalized land use map of Lake Lemon's watershed.

TABLE 2-5. LAND USES IN THE MAJOR BASINS WITHIN LAKE LEMON'S WATERSHED[1]

Basin	Land Use (acres /%)				
	Forest	Agriculture	Residential	Ponds	Campgrounds
North Fork Beanblossom Creek	5,490/67	2,440/30	124/1	186/2	0
Upper Beanblossom Creek (east of North Fork)	7,980/69	3,270/28	141/1	140/1	63/1
Lick Creek	2,460/61	1,290/32	172/4	87/2	0
Bear Creek	4,350/90	370/8	22/1	58/1	54/1
Plum Creek	2,560/93	175/6	17/1	12/1	0
Beanblossom Creek (at Lake Lemon)	2,7940/76	7,565/21	510/1	486/1	117/1

[1]Estimated from vertical ASCS aerial photographs using a polar planimeter.

2.7 PUBLIC ACCESS AND TRANSPORTATION

Public transportation to the Lake Lemon area is limited. State Route 45 is the major road through the Lake Lemon watershed. Bloomington Transit busses travel along SR 45, but only as afar as Eastern Heights, which is at least ten km from the lake. The only other public transportation available is taxi service from Bloomington, which is approximately a $12.00 one-way fare from downtown Bloomington. The majority of Lake Lemon visitors travel by private automobile, bicycle, recreational vehicle, or church/organization bus.

There are no free public boat launching facilities on Lake Lemon. Boats may be launched for a fee ($3.00 for non-motorized, $6.00 for motorboats) at Riddle Point (a City of Bloomington park) or at two marinas on the lake. Public fishing access is available along the South Shore Drive causeway on the southern shore, along the Shuffle Creek embayment and adjacent causeway, and at the spillway. None of the undeveloped areas of public access have more than just a few off-road parking spaces.

2.8 STATE NATURAL AREAS AND RARE SPECIES

There are three state natural areas within Lake Lemon's watershed (Figure 2-6) (Indiana Natural Heritage Program, 1991). These are:

1. Trevlac Bluffs - eastern hemlock slope, privately owned.
2. Helmsburg Knobs - forested natural area, privately owned.
3. Lilly-Dickey Woods - forested natural area owned by Indiana University.

Trevlac Bluffs and Helmsburg Knobs both adjoin the flood plain of Beanblossom Creek and may, depending on where the actual property lines are, be subject to erosion by the creek.

There are eighteen rare, threatened or endangered plant and animal species known to occur within Lake Lemon's watershed. These are listed in Table 2-6 below. Current management activities are not known to have any adverse impact on these species.

TABLE 2-6. Rare, Threatened and Endangered Species Occurring Within Lake Lemon's Watershed.

SPECIES	STATUS
Lynx rufus (bobcat)	state endangered
Haliaeetus leucocephalus (bald eagle)	state & federally endangered
Buteo platypterus (broadwinged hawk)	special concern
Wilsonia citrina (hooded warbler)	special concern
Clonophos kirtlandii (Kirtland's snake)	state threatened, federal candidate
Crotalus horridus (timber rattlesnake)	special concern
Panicum bicknellii (panic grass)	state endangered
Spiranthes orcholeuca (yellow nodding ladies'-tresses)	state endangered
Lilium superbum (turk's cap lily)	state threatened
Spiranthes ovalis (lesser ladies'-tresses)	state threatened
Desmodium leavigatum (smooth fick-trefoil)	state rare
Desmodium viridiflorum (velvety tick-trefoil)	state rare
Linum striatum (ridged yellow flax)	state rare
Rubus deamii (Deam's dewberry)	state rare
Synandra hispidula (Guyandotte beauty)	state rare
Monotropa hypopithys (American pinesap	watch list
Plantanthera peramoena (purple fingless orchis)	watch list
Tsuga canadensis (eastern hemlock)	watch list

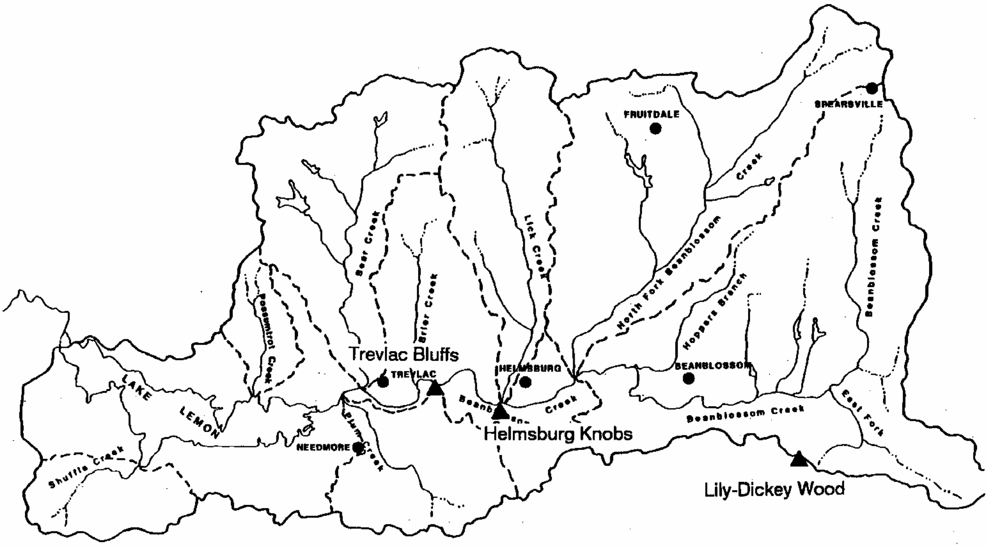


Figure 2-6. Location of State Natural Areas.

3.0 LAKE QUALITY

3.1 WATER QUALITY

3.1.1 Methods

Water samples were collected over the deepest part of Lake Lemon on 24 July 1990 (Figure 2-2). This site corresponds with Site B used during the Phase I Study. Samples were collected from one meter below the surface (epilimnion) and one meter off the bottom (hypolimnion). Collected samples were all analyzed according to the 17th edition of <u>Standard Methods</u>, (APHA, 1989). In addition, dissolved oxygen and temperature measurements were made at one meter intervals, light transmission data were collected using a Secchi disk and a light meter. A single plankton tow was taken from the 1% light level to the surface, according to IDEM's revised procedure for calculating plankton eutrophy points (see Table 3-3).

3.1.2 Results

The temperature data displayed in Figure 3-1 shows that Lake Lemon is just weakly stratified. The relatively shallow depth, long wind fetch and hydraulic flow-through all contribute to keeping the water column mixed. Because of this, there is little change in temperature with depth. Surface temperatures are somewhat cool for a lake in southern Indiana during summer and may also reflect the influence of streamflow, with its cooler water temperature, on Lake Lemon.

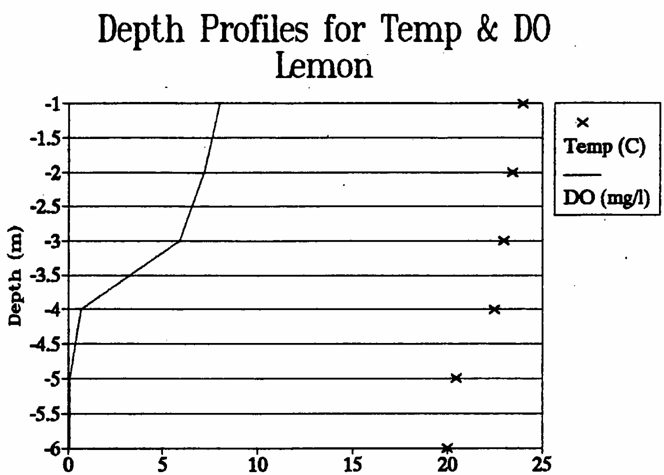


Figure 3-1. Temperature and dissolved oxygen profiles for Lake Lemon.

Despite the lack of thermal stratification, the oxygen profile resembles that of a stratified system. D.O. concentrations drop sharply below three meters and there is insufficient D.O. for aquatic life below four meters. This suggests that respiration rates (oxygen-consuming) are high in the hypolimnion, due likely to bacterial decomposition of organic matter.

The elevated ammonia (NH_4) concentration in the hypolimnion (Table 3-1) confirms this because ammonia is generated as a by-product of bacterial decomposition. Total and soluble reactive phosphorus (SRP) concentrations are also elevated in the hypolimnion suggesting some chemical release of SRP from the sediments under the anoxic conditions present. Total phosphorus (TP) and organic nitrogen concentrations are characteristic of over-productive, or eutrophic lakes.

Secchi disk transparency and light transmission are both low in Lake Lemon. The low levels are indicative of the presence of sufficient suspended particulates in the water to reduce light penetration. High suspended sediment loads were observed in Beanblossom Creek during the Phase I Study (Zogorski et al., 1986) and this likely contributes to the reduced transparency in the lake today.

Plankton concentrations were only 2,316 cells per liter and species composition was reasonably diverse (Table 3-2). Just over 50 percent (50.3%) of all plankton were blue-green algae which are considered nuisance species.

3.1.3 Trophic State Index

Water quality data collected were used in the Indiana Department of Environmental Management's (IDEM) trophic state index (TSI) (Table 3-3). A TSI is a numerical index representing a lake's eutrophication or productivity status. The Indiana TSI ranges from 0 (highest quality) to 75 (worst quality). Results for the 1990 data (Table 3-1) show that Lake Lemon scored 28 eutrophy points. This is considered "intermediate quality" in the TSI (IDEM, 1986). Most of the eutrophy points were assigned because of poor transparency and blue-green algae dominance of the plankton.

Lake Lemon's TSI was last calculated in the mid-1970's when the lake scored 37 points which is also in the intermediate quality class. Because the TSI water quality parameters, and thus the index itself, are affected by natural seasonal variations (for example, air temperature, precipitation, time of sampling), we cannot say with any certainty that the nine point TSI reduction reflects an improvement in overall lake conditions.

3.1.4 Comparison With Phase I Study

Table 3-4 compares the water quality data collected for this study with data collected during the same time period in 1982 during the Phase I Study. Nutrient concentrations in the 1982 sampling were generally lower than those in 1990. Although eutrophy points were not assigned to the 1982 data originally, we can assign points after the fact to July 1982 data for comparison with the July 1991 data. A total of eight eutrophy points were

TABLE 3-1. WATER QUALITY DATA - JULY 24, 1990

PARAMETER	EPILIMNION	HYPOLIMNION	MEAN	EUTROPHY POINTS
Total P (mg/L)	0.022	0.089	0.06	3
SRP (mg/L)	0.003	0.053	0.03	1
NO_3 (mg/L)	0.095	0.114	0.10	0
NH_4 (mg/L)	0.015	0.745	0.38	1
Org-N (mg/L)	1.223	1.539	1.38	3
pH	7.3	6.7	7.0	-
Conductivity (umhos)	175.0	160.0	167.5	-
Alkalinity (mg $CaCO_3$)	57.75	85.05	71.40	-
Secchi disk (ft)	3.28			6
D.O. % saturation	90.28			0
D.O. % oxic	66.67			1
Light transmission at 3 feet (%)	32.0			3
Plankton Tow (cells/L)	2316			0
Blue-Green Dominance	yes			10
			TOTAL POINTS	28

TABLE 3-2. Plankton Species Composition in Lake Lemon on 7-24-90.

SPECIES	ABUNDANCE (#/1)
<u>Blue-Green Algae (Phylum: Cyanophyta)</u>	
Anabaena	171
Apahnizomenon	839
Coelosphaerium	14
Oscillatoria	57
<u>Green Algae (Phylum: Chlorophyta)</u>	
Ulothrix	284
<u>Yellow-Brown Algae (Phylum: Chrysophyta)</u>	
Mallomonas	171
Rhizosolenia	142
Synedra	43
<u>Dinoflagellates (Phylum: Pyrrophyta)</u>	
Ceratium	14
<u>Rotifers (Phylum: Rotifera)</u>	
Asplanchna	14
Chromogaster	43
Difflugia	142
Keratella	142
Polyarthra	71
Pompholyx	14
<u>Zooplankton (Phylum: Arothropoda)</u>	
Bosmina	28
Daphnia	14
Diaphanizoma	28
Ceriodaphnia	14
Cyclopoid copepod	28
Nauplii	43

TABLE 3-3. Calculation of the IDEM lake trophic state index.

Parameter and Range		Eutrophy Points
I.	Total Phosphorus (ppm)	
	A. At least 0.03	1
	B. 0.04 to 0.05	2
	C. 0.06 to 0.19	3
	D. 0.2 to 0.99	4
	E. 1.0 or more	5
II.	Soluble Phosphorus (ppm)	
	A. At least 0.03	1
	B. 0.04 to 0.05	2
	C. 0.06 to 0.19	3
	D. 0.2 to 0.99	4
	E. 1.0 or more	5
III.	Organic Nitrogen (ppm)	
	A. At least 0.5	1
	B. 0.6 to 0.8	2
	C. 0.9 to 1.9	3
	D. 2.0 or more	4
IV.	Nitrate (ppm)	
	A. At least 0.3	1
	B. 0.4 to 0.8	2
	C. 0.9 to 1.9	3
	D. 2.0 or more	4
V.	Ammonia (ppm)	
	A. At least 0.3	1
	B. 0.4 to 0.5	2
	C. 0.6 to 0.9	3
	D. 1.0 or more	4
VI.	Dissolved Oxygen Percent Saturation at 5 feet from surface	
	A. 114% or less	0
	B. 115% 50 119%	1
	C. 120% to 129%	2
	D. 130% to 149%	3
	E. 150% or more	4

TABLE 3-3 (continued)

VII.	Dissolved Oxygen Percent of measured water column with at lease 0.1 ppm dissolved oxygen	
	A. 28% or less	4
	B. 29% to 49%	3
	C. 50% to 65%	2
	D. 66% to 75%	1
	E. 76% 100%	0
VIII.	Light Penetration (Secchi Disk)	
	A. Five feet or under	6
IX.	Light Transmission (Photocell) Percent of light transmission at a depth of 3 feet	
	A. 0 to 30%	4
	B. 31% to 50%	3
	C. 51% to 70%	2
	D. 71% and up	0
X.	Total Plankton per liter of water sampled from a single vertical tow between the 1% light level and the surface:	
	A. less than 3,000 organisms/L	0
	B. 3,000 - 6,000 organisms/L	1
	C. 6,001 - 16,000 organisms/L	2
	D. 16,001 - 26,000 organisms/L	3
	E. 26,001 - 36,000 organisms/L	4
	F. 36,001 - 60,000 organisms/L	5
	G. 60,001 - 95,000 organisms/L	10
	H. 95,001 - 150,000 organisms/L	15
	I. 150,001 - 5000,000 organisms/L	20
	J. greater than 500,000 organisms/L	25
	K. Blue-Green Dominance	10 additional points

TABLE 3-4. WATER QUALITY DATA COMPARISON: 1982-1990

	JULY 24, 1990		JULY 21, 1982	
PARAMETER	MEAN	EUTROPHY POINTS	MEAN	EUTROPHY POINTS
Total P (mg/L)	0.06	3	0.028	0
SRP (mg/L)	0.03	1	0.01	0
NO_3 (mg/L)	0.10	0	0.20	0
NH_4 (mg/L)	0.38	1	0.27	0
Org-N (mg/L)	1.38	3	<0.1	0
pH	7.0	-	7.2	-
Conductivity (umhos)	167.5	-	-	-
Alkalinity (mg $CaCO_3$)	71.40	-	63.0	-
Secchi disk (ft)	3.28	6	3.0	6
D.O. % saturation	90.28	0	94	0
D.O. % oxic	66.67	1	75	1
Light transmission at 3 feet (%)	32.0	3	-	-
Plankton Tow (cells/L)	2,316	0	-	- [a]
Blue-Green Dominance	yes	10	yes	10

[a] 1982 plankton reported as biomass which is not comparable to density enumeration used in the Indiana TSI.

assigned to nutrient concentrations based on the 1990 data but no eutrophy points would have been assigned for the 1982 nutrient data. Because light data were not collected in 1982 and because plankton data were reported in different units, we cannot calculate a total TSI for the 1982 data.

3.2 FISHERIES

The 1982 fish management report prepared by the Indiana Department of Natural Resources (DNR) was included as Appendix C in the Phase I Report. In 1984 the DNR stocked 507 adult white bass in an attempt to establish a self-sustaining population by utilizing the abundant forage at Lake Lemon. A spot check survey was conducted in September 1988 to evaluate the success of the white bass stocking (Andrews, 1988). However, no white bass were collected during the two-night gill net survey. The DNR concluded that white bass were not likely to offer significant fishing opportunities or predation on forage fish.

If local funds became available, the DNR recommends developing a supplemental predator stocking program on Lake Lemon. Hybrid white bass would probably be the best choice for this program. However, IDNR experience at other Indiana lakes having rapid flushing rates suggest that emigration of stocked fish could limit success.

3.3 ROOTED MACROPHYTES

One of the most pervasive problems in Lake Lemon continues to be the excessive growth of Eurasian water milfoil (*Myriophyllum spicatum*) in nearly all areas of the lake up to three meters in depth. Sediment deposition in the eastern end of the lake as well as the lake's morphology provide for extensive shallows. For example, the Phase I Study estimated that milfoil infestation covered 225 acres (91 ha) of the lake's surface area. Milfoil interferes with navigation, "pumps" nutrients from the sediments, is a source of BOD, and may promote stunted fish (see Zogorski et al. (1986) for more detail).

Following the recommendations of the initial Phase I report (Zogorski et al., 1986), the City of Bloomington purchased a mechanical harvester to control milfoil in Lake Lemon. Since that time, an average of approximately 100 acres (175 wet tons of milfoil) have been harvested annually. Aquatic herbicides are used selectively in shallow areas where the harvester cannot operate. Winter drawdown has been effective in reducing macrophyte growth the following season, however, limited outlet capacity and a broken outlet gate have restricted the use of this cost-effective technique.

4.0 POLLUTION SOURCES

4.1 OVERVIEW

A specific goal of this study was to investigate more closely, existing and potential sources of pollution. Pollution entering lakes can be divided into two broad types: point and non-point. Point source pollution can be thought of as that which comes from a discrete point, for example a discharge pipe. Point sources are relatively easy to identify and are often regulated by state and federal statutes. Non-point sources are diffuse in nature. NPS pollution includes runoff from agricultural lands and parking lots, erosion from construction sites, etc. The U.S. Environmental Protection Agency (1989) estimates that 76% of all pollution to lakes in the U.S. is of non-point origin.

4.2 POINT SOURCES

There are three point source discharges in the Lake Lemon watershed that require NPDES (National Pollutant Discharge Elimination System) permits. All three are small wastewater treatment plants having seasonal use (Table 4-1). The total combined design flow for the three is 27,300 gpd. Camp Gallahue has the largest single design flow of 13,000 gpd, however records suggest that this system does not discharge into surface waters.

Records of phosphorus and nitrogen discharge from these facilities are not available so it is difficult to evaluate their impact on Lake Lemon. All three facilities are 4-5 river miles upstream from Lake Lemon and the small and seasonal nature of the discharges suggest that their impacts are negligible.

4.3 NONPOINT SOURCES

Nonpoint sources of pollution to Lake Lemon can be grouped into three categories: shoreline and streambank erosion, poorly-treated septic system effluent and watershed sources generally.

4.3.1 Shoreline Erosion

Shoreline erosion is a significant problem in a number of areas along Lake Lemon's shoreline. We estimate that 1400 feet of shoreline need erosion control treatment (Figure 4-1). Eroded banks in these areas are up to fifteen feet high. Most of the shoreline soils are silt loams (see Section 2.5 of the Phase I report). Approximately 80 percent of the eroded shoreline is owned by the City of Bloomington. The lake's shallow water depth, long wind fetch, heavy motor boat use, fluctuating water levels and rapid flows during runoff events all contribute to the shoreline erosion problem.

TABLE 4-1. Status of Wastewater Treatment Facilities in Lake Lemon's Watershed.

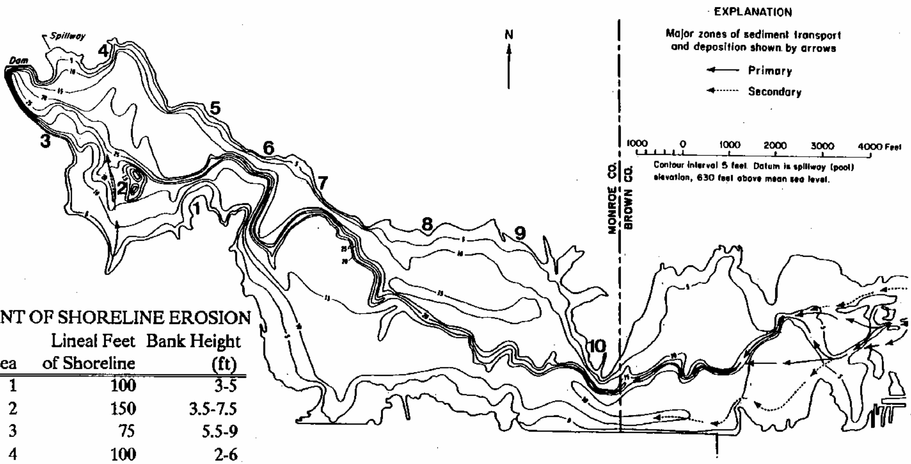
Facility	Location	NPDES Requirements
Camp Gallahue Brown County IN 00538999 Jack Creek (seasonal)	SE1/4, SW1/4 S18 T10 R2	Design flow 13,000 gpd controlled discharge (requires streamflow measurements for proper dilution and discharge only between Nov. 1 - April 30; CBOD 25/40, TSS 70/105, pH 6.0-9.0;
Helmsburg School Brown County IN 0049891 Trib. to Bear Cr.	SE1/4, NE1/4, SE1/4 S27 T10 R2	Design Flow 6,700 gpd; BOD 30/45, TSS 30/45, pH 6.0-9.0, Cl_2 0.5-1.0
Lutheran Hills Brown County IN 0039110 Bear Creek (seasonal)	SW1/4, SE1/4 SW1/4 S20 T10 R2	Design flow 7,600 gpd; BOD 10/15, TSS 10/15, pH 6.0-9.0, Cl_2 0.5-1.0

4.3.2 Streambank Erosion

Streambank erosion is a serious problem along lower Plum Creek and lower Beanblossom Creek from its mouth to the juction of the North Fork three miles east of Helmsburg. The deep, silty alluvial soils in these areas are easily eroded by the rather substantial floodwaters that characterize Beanblossom Creek. For example, extreme discharges through lower Beanblossom Creek range from near zero to an historic maximum (on 6-23-60) of approximately 27,000 cfs (Zogorski et al., 1986). In the 1988 water year, discharge through lower Beanblossom Creek averaged 30.4 cfs with a maximum of 3,200 cfs (Glatfelter et al., 1989).

These large discharge variations and the silty, alluvial soils leave eroded streambanks along lower Beanblossom Creek up to twenty feet high (Figure 4-2). Silt deposits on forested floodway terraces can be up to one foot thick following spring floods.

Many streambanks along the upper reaches of the watershed are also eroded but the problem isn't as severe nor are the eroded banks as high. Erosion in these areas is promoted by livestock trampling the banks, landowners clearing brush and timber from the streambanks, and farmers plowing up to the edge of the banks.



EXTENT OF SHORELINE EROSION

Area	Lineal Feet of Shoreline	Bank Height (ft)
1	100	3-5
2	150	3.5-7.5
3	75	5.5-9
4	100	2-6
5	100	2-8
6	150	2-10
7	400	2-15
8	100	2-8
9	75	2-6
10	150	4-15

Figure 4-1. Extent of shoreline erosion around Lake Lemon.

Lower Beanblossom Creek

Plum Creek

Figure 4-2. Examples of streambank erosion.

4.3.3 Septic System Failure

Effluent from improperly installed and/or maintained on-site septic systems may contribute quantities of nutrients, bacteria and biological oxygen demand (BOD) to Lake Lemon. Slow percolation rates and steep slopes characterize the shoreline soils. Because of this, only five percent of the shoreline soils are classified as moderately suitable for the development of septic systems (Thomas, 1981; Noble et al., 1990; Zogorski et al., 1986).

Analyses conducted during the Phase I study showed elevated fecal coliform bacteria levels along the shorelines of lower Beanblossom Creek and in channels within the Chitwood Addition, a residential area at the southeast corner of the lake. Lots in these areas are often undersized and have high water tables - factors that contribute to septic system failure. The status of these septic systems remains essentially unchanged since the Phase I study was completed.

4.3.4 Watershed Sources and AGNPS Modeling

Potential watershed nonpoint sources of pollution are numerous. Sources of such pollution include soil erosion and sedimentation on rural and urban land, eroding streambanks, and nutrient and organic materials from livestock wastes and agricultural land (Young et al. 1987). The identification of specific nonpoint sources is difficult because these sources are often distributed over the entire area of a lake's watershed. To assist us in identifying potential nonpoint sources in Lake Lemon's watershed and assessing their magnitude, we used the Agricultural Nonpoint Source Model (AGNPS).

The AGNPS model was developed by the Agricultural Research Service (ARS) in cooperation with the Minnesota Pollution Control Agency and the Soil Conservation Service (SCS). The model was developed to analyze and provide estimates of runoff water quantity and quality from agricultural watersheds ranging in size from a few hectares to upwards of 20,000 ha (50,000 acres). AGNPS provides information on runoff volume and peak runoff, and estimates upland erosion, channel erosion, and sediment yield. In addition, AGNPS estimates the concentrations and masses of nitrogen (N), phosphorus (P), and chemical oxygen demand (COD) contained in the runoff and the sediment.

Methods

AGNPS is event-based. As such, it works only for a single storm event of known volume and intensity. For Lake Lemon, we used a 3.9 inch rainstorm with an intensity of 90 foot-tons per acre-inch. This represents conditions that would be expected during a 24-hour storm with a frequency of once every five years. These values were obtained from the Soil Conservation Service (1966) from data for Indiana.

Because AGNPS can be run only for single storm events, annual yields of runoff, sediment and nutrients from the modeled watershed cannot be calculated. However, the model is still useful in comparing relative yields of these materials from specific watershed areas. In this way, AGNPS can be used to identify "hot spots" in the watershed that require management.

U.S. Geological Survey 7.5 minute topographical maps of the Hindustan, Morgantown, Beanblossom, Unionville, Belmont and Nashville quadrangles (scale 1:24,000) were used as a base map for Lake Lemon and its watershed. Clear acetate containing a grid of cells was laid over the base map. Each cell represented 40 acres. Only those cells with more than 50 percent of their area within the watershed boundaries were included. For Lake Lemon, a total of 1125 cells were required to cover the entire watershed (Figure 4-3).

For each of the cells in the Lake Lemon watershed, 22 separate parameters were determined. The following is a brief description of each parameter.

Cell Numbering. Each cell was numbered beginning in the northwest corner of the watershed and proceeding from west to east, southward. This numbering scheme, used in AGNPS for labeling cells, aided in quickly identifying specific cells in the program's output (see Figure 4-3).

Receiving Cell. The receiving cell is the number of the cell into which the most significant portion of the runoff from another cell drains. As arrows showing flow to receiving cells are connected, the patterns of surface water drainage within the watershed emerge. Figure 4-4 illustrates the surface water drainage pattern for the entire watershed. Lake Lemon's outlet at Beanblossom Creek is at cell #621.

SCS curve number. The SCS (Soil Conservation Service) runoff curve number is used to estimate the direct runoff following storm rainfall. The amount of runoff is influenced not only by the amount of rainfall per storm, but also the amount of moisture in the soil prior to the storm (the more water in the soil, the less rain can penetrate into the soil, the more rain runs over the land). To keep the analyses constant, an average soil moisture condition was assumed. The values of the SCS curve number were obtained from a table in the AGNPS manual (Young et al., 1987) by matching land use descriptions with the hydrologic soil type of the major soils in the cell. Webased land use designations on areal photos and field checks. If more than one land-use was present in a cell, a weighted average value was calculated.

Land Slope. Land slope influences the velocity of storm runoff and therefore the extent to which soil erodes. The land slope (in percent of rise) was determined from information provided by the Monroe and Brown County District Conservationists (Joe Peden and Jim Blank) based on the relationship between soil type and land slope.

Slope Shape Factor. The shape of the land surface within each cell was numbered one, two, or three for uniform, convex or concave slopes respectively. The slope shape factor was determined by examining the contour lines on the topographical maps.

Field Slope Length. The field slope length was determined from information provided by the Monroe and Brown County Soil Conservation Service Agents and based on a weighted average of the soil types found in the individual cells.

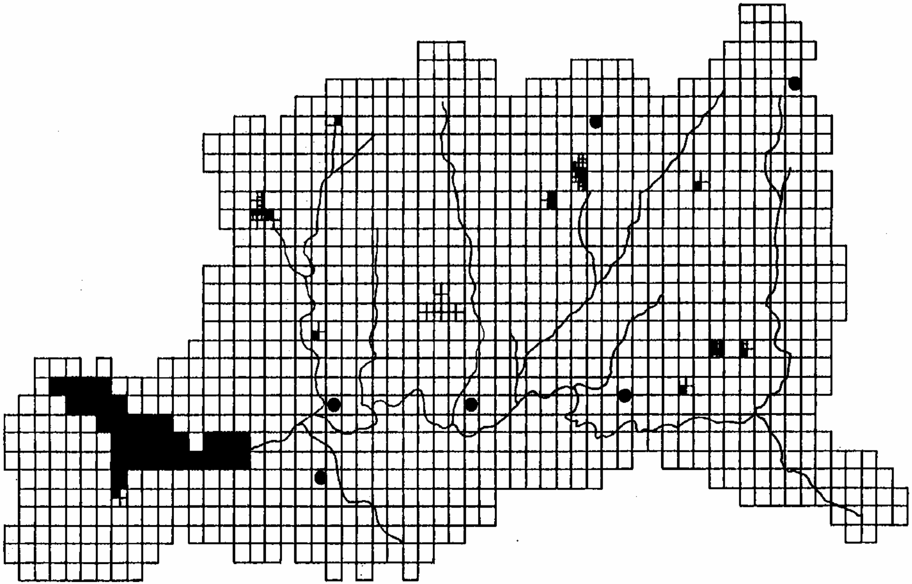


Figure 4-3. AGNPS cells in Lake Lemon's watershed with major streams and towns indicated.

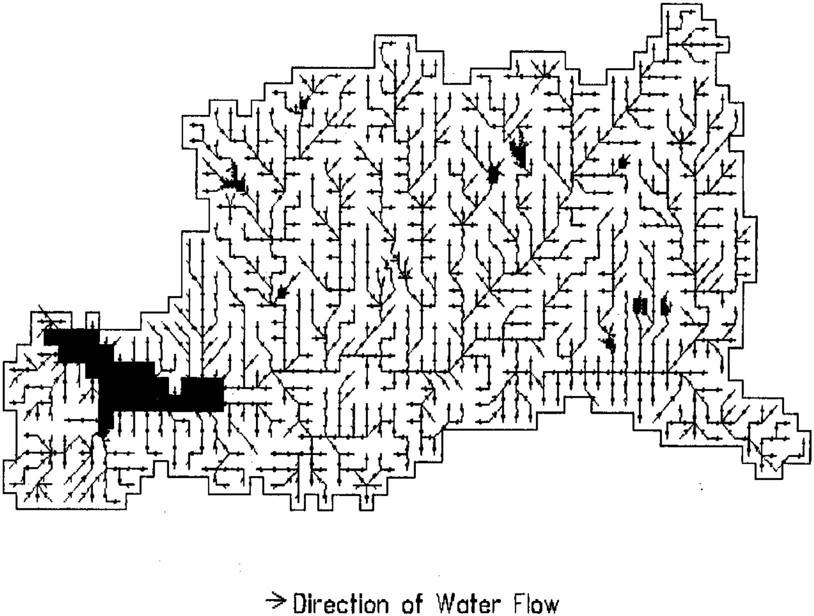


Figure 4-4. Surface drainage patterns in the Lake Lemon watershed.

Channel Slope. The channel slope was the average slope (in percent of rise) of the defined channel(s) within each cell that were visible on the topographic maps. If there was no definable channel within the cell, we input one-half the landslope value for the channel slope.

Channel Sideslope. The channel sideslope is the average sideslope (in percent) of the channel(s) within each cell. We estimated channel sideslopes in the field at representative points in the watershed and extrapolated from these for input values for the rest of the channels in the watershed.

Manning's Roughness Coefficient. The flow velocity of runoff depends on the roughness of the channel in which it flows. The rougher the channel bottom, the slower the water moves and therefore, the lower the erosive power. The Manning's roughness coefficient varies between zero and one (the higher the number, the smoother the surface), depending on the type of channel bottom. Roughness was estimated in the field at representative points in and extrapolated to the rest of the channels in the watershed. If no channel was definable within the cell, the roughness coefficient was chosen according to the main surface condition in the cell. If the cell was mainly water or marsh a value of 0.99 was used.

Soil Erodibility (K) Factor. The K-factor is also used in the Universal Soil Loss Equation (USLE). Its value varies between zero and one; the higher the number, the more erodible the soil. K-factors were taken from values reported in the soil surveys. If the cell was mainly water or marsh, a value of zero was used.

Cover and Management (C-factor). Another USLE parameter, the C-factor is used to represent the cover and management of the land within the Lake Lemon watershed. Values are related to land use and in the case of agriculture, the crop and tillage practice used. For example, C-factors for corn after soybeans vary from 0.41 for conventional tillage, 0.29 for chisel plowing and 0.09 for no-till. We used a value of 0.20 for all agricultural lands in the Lake Lemon watershed. Conventional, chisel and no-till cultivation practices are all used in the Lake Lemon watershed, however most farmers use, or are encouraged to use, no-till methods. For forest land, we used a value of 0.02. Values for forest land range from 0.0001 for undisturbed woodland with 100% canopy, to 0.35 for harvested woodlands. We used C-factor values of 0.01 for residential and 0 for water or wetlands.

Support Practice (P) Factor. The P-factor is a parameter used in the Universal Soil Loss Equation to represent various conservation practices on agricultural lands. The worst-case condition during the fallow or seedbed periods is represented by a value of one for agricultural and urban lands. If the cell was mainly water or marsh, zero was used.

Surface Condition Constant. The surface condition constant was based on the land use at the time of the storm to make adjustments for the time overland flow takes to channelize. The lower the value, the greater the overland flow velocity. Values were taken from Table 2 of the AGNPS manual.

Cell Aspect. The cell aspect is defined as the direction of flow leaving each cell. Each of the eight possible flow directions were numbered, beginning with number 1 at the northern position and proceeding clockwise to number 8 at the northwestern position.

Soil Texture. The major soil texture found within each cell was characterized as either water, sand, silt, clay, or peat by using the Monroe and Brown County Soil Surveys (Thomas, 1981; Noble et al., 1990) and the textural triangle found in Young et al. (1987).

Fertilization Level. The fertilization level was a single digit designation for the level of fertilization on each agricultural field. In general, medium levels of fertilization were assumed for all agricultural lands based on the recommendation of Joe Peden, Monroe County SCS District Conservationist. Zero fertilization was used for water and wetlands, and low levels for urban conditions.

Fertilizer Availability Factor. The fertilizer availability factor is the percentage of fertilizer left in the top half inch of soil at the time of the storm. If none of the fertilizer had been incorporated into the soil, 100% (the worst case) would be available. For agricultural land, we used a value of 67% to characterize chisel plow tillage practices except in areas where the SCS District Conservationists new otherwise. Where water or marsh conditions were found, a value of zero was used. If a cell was primarily urban or forest, 100% was used.

Point Source Designator. The point source designator is a single digit representing the number of discrete pollution sources (feedlots, springs, waste treatment plants, etc.) found within each cell. The Lake Lemon watershed had no significant point sources designated.

Gully Source Level. While the AGNPS model provides estimates of soil erosion from channels and various land surfaces, it may underestimate soil losses from gullies. If desired, the modeler may make an on-site estimate of tons of soil lost from gullies and enter the amount under this parameter. We saw little evidence of gully erosion outside of established channels and for what little we did see, we were unable to visually estimate the tons of soil that could be lost during our moded storm event.

Chemical Oxygen Demand (COD). Oxygen that is consumed or removed from the lake by nonbiological combination with chemicals in the water and mud is called the Chemical Oxygen Demand or COD. The values for the COD per cell depend directly on the land uses, from zero for water to 170 mg/l for row crops, and were obtained from Table 8 in the AGNPS manual. The higher the COD value, the more oxygen will be removed.

Impoundment Factor. The impoundment factor indicates the presence of an impoundment terrace system within the cell. Since no impoundment terrace systems were found within the Lake Lemon's watershed, this parameter was set to zero.

Channel Indicator. The channel indicator denotes the presence of a defined channel within the cell: zero indicates no defined channels; any other number signifies the number of channels in the cell.

Once the 22 parameters were compiled for each of the 1125 cells within the Lake Lemon watershed, the model was run.

Subdivisions

The current version of AGNPS does not account for the effects of lakes and ponds within a modelled watershed. The only way we could distinguish the many small reservoirs in Lake Lemon's watershed from channels was to input values for the cell which represented water. We therefore subsdivided the following cells to better represent the size of small reservoirs within the cells: 98, 196, 235, 243, 254, 273, 294, 295, 468, 509, 510, 511, 544, 612, 614, 710, and 990.

AGNPS Results

The following figures show the results for the AGNPS model run with a 3.9 inch rainfall having an intensity of 90 foot-tons per acre-inch. The greatest amount of runoff (Figure 4-5) and soil erosion per cell (Figure 4-6) for the simulated storm event is in the upper ends of the watershed, where most of the agricultural activity occurs. Five 40-acre cells had mean soil erosion rates between 0.75 - 0.92 tons/acre (the highest category) for the modeled storm. All of these cells and all of the cells in the next highest category (0.5 - 0.75 tons/acre) occur on primarily agricultural lands. Although most agriculture occurs on relatively flat bottomlands or ridges, the removal of vegetation during cultivation significantly increases both runoff and soil loss.

Sediment yield (delivery) patterns follow stream courses, because the streams ultimately receive and transport soils eroded from the land (Figure 4-7. Heaviest sediment yield is in the Beanblossom Creek main branch and North Fork. Note the cumulative effect of soil additions from the headwaters to the lower portions of the creek. At the mouth of Beanblossom Creek, 1066 tons of eroded soil enters Lake Lemon from this single simulated storm event. Lesser sediment yields are visible for Bear Creek and Lick Creek. Streambank erosion is often severe and may also contribute to the sediment yields observed.

Because phosphorus is most often the nutrient that limits algal production in lakes, much attention is given to phosphorus concentrations in lakes. Sediment phosphorus is that phosphorus which is adsorbed to or incorporated into inorganic and organic particles. As such, high sediment phosphorus yields are associated with areas of high soil erosion and/or high phosphorus availability. Sediment phosphorus losses within the 40-acre cells due to the modeled storm event ranged up to 1.84 lbs/acre (Figure 4-8). All cells with yields greater than 0.5 lbs/acre had agriculture as the dominant land use.

Soluble phosphorus, on the other hand, is in dissolved form and AGNPS uses fertilization levels, phosphorus availability at the soil surface, and

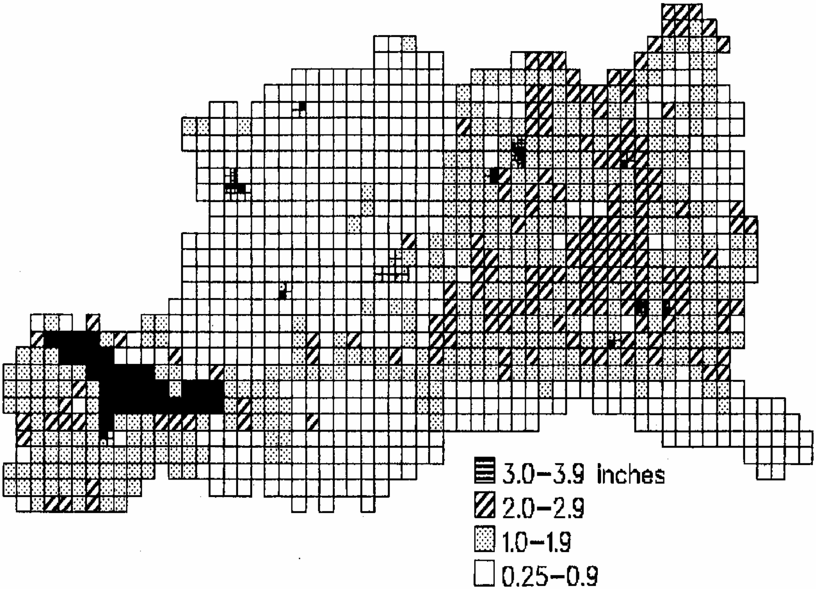


Figure 4-5. Runoff volume predicted by AGNPS for modeled storm event.

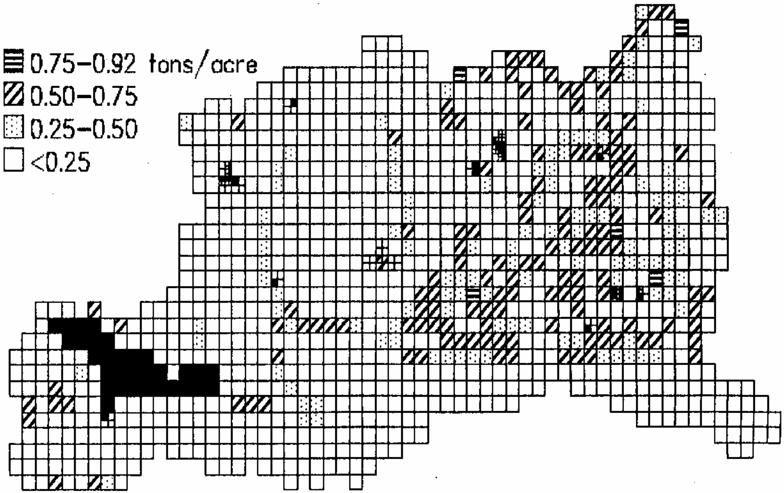


Figure 4-6. Cell soil losses during modeled storm event.

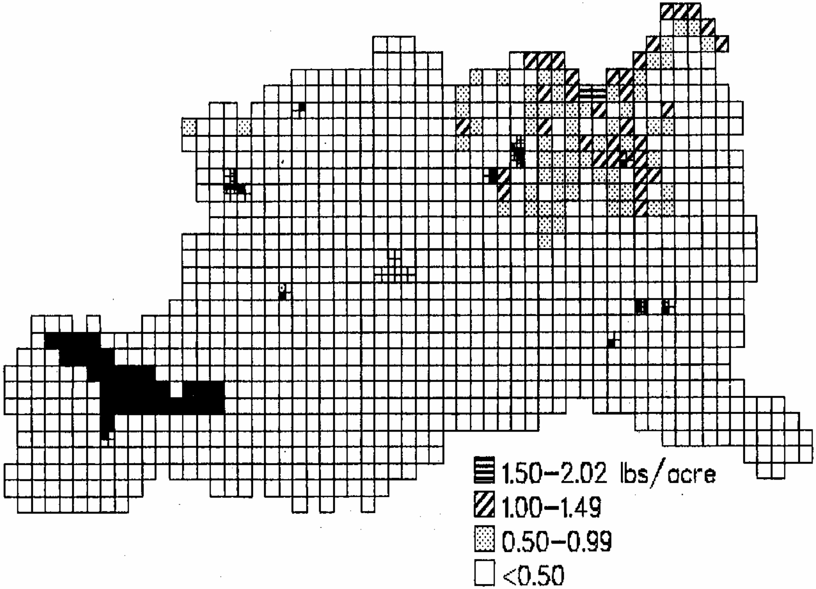


Figure 4-8. Sediment phosphorus yields for modeled storm event.

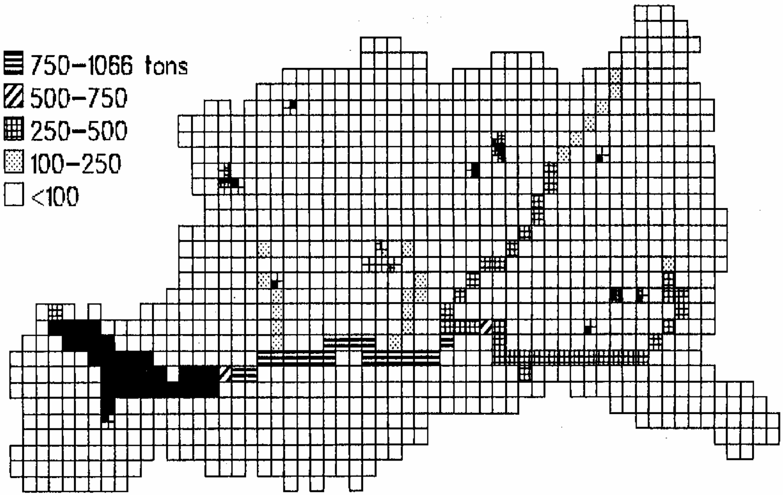


Figure 4-7. Sediment yields for the modeled storm event.

TABLE 4-2. Total Phosphorus Export Associated with Various Land Uses. (Source: Reckhow et al., 1980)

Land Use	Total Phosphorus Loss (lbs/acre/yr) Median	75%	25%	Maximum	Minimum
Row Crops	2.0	4.7	0.8	16.6	0.1
Non-row Crops	0.6	1.3	0.4	2.6	0.1
Pasture	0.7	2.4	0.2	4.4	0.1
Urban	1.0	2.5	0.3	5.5	0.2
Feedlots	228	375	152	709	13.4

total runoff to estimate soluble phosphorus losses (Young et al., 1989). Soluble phosphorus yields due to the modeled storm event reached a maximum of 2.02 lbs/acre (Figure 4-9). Only 36 cells had soluble phosphorus losses greater than 1.0 lb/acre and these cells were located in the northeastern portion of the watershed, some distance from Lake Lemon.

Phosphorus losses from Lake Lemon's watershed were greatest on the agricultural lands. Most phosphorus export data in the scientific literature is annualized. Thus it is difficult to compare AGNPS single-event data to annualized data. Reckhow et al. (1980) reviewed the available literature to summarize phosphorus losses from various land uses. Their results are summarized in Table 4-2. The median total phosphorus loss from land in row crops was 2.0 lbs/acre/year. The mean sediment phosphorus export to Lake Lemon at the mouth of Beanblossom Creek for the single modeled storm event was 0.18 lbs/acre. The equivalent soluble phosphorus export was 0.11 lbs/acre, for a mean total phosphorus export to Lake Lemon of 0.29 lbs/acre for the single storm. At this rate, the annual total could be less than 2.0 lbs/acre/year but we can only speculate at this stage. However, sixty-nine cells in Lake Lemon's watershed had average sediment phosphorus losses for the single modeled storm event greater than Reckhow's 2.0 lbs/acre/year median value. This suggests that phosphorus management is needed on those AGNPS cells in Lake Lemon's watershed having the greatest phosphorus losses.

Sediment and soluble nitrogen yields from each 40-acre cell are given in Figures 4-10 and 4-11. Again, highest yields for the simulated storm event are from primarily agricultural lands to the west and north of the lake. Nitrogen is a primary plant nutrient that is applied as fertilizer to agricultural crops and lawns. It also occurs naturally in organic matter (leaves, twigs, manure, etc.). Nitrogen is highly soluble and often is found in dissolved form. Because of this, the AGNPS model predicts that more soluble nitrogen than sediment nitrogen would be exported during the storm event.

Total yields for each cell draining a sub-watershed of Lake Lemon are presented in Table 4-3. Cell totals are cumulative for everything above the

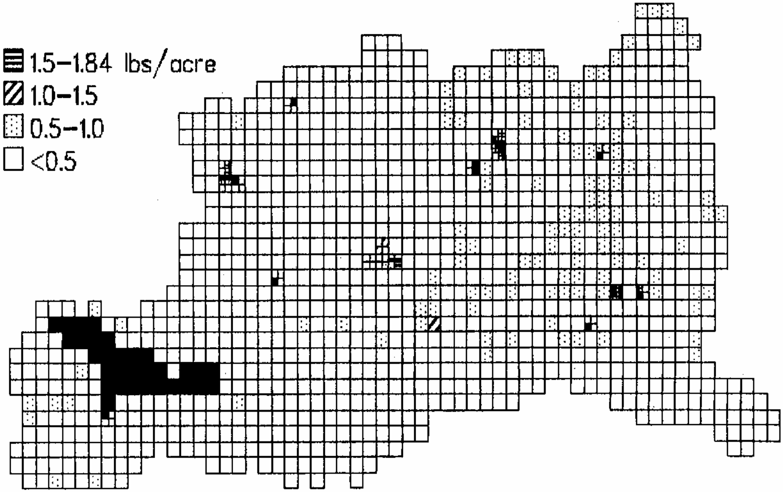


Figure 4-9. Soluble phosphorus losses for the modeled storm event.

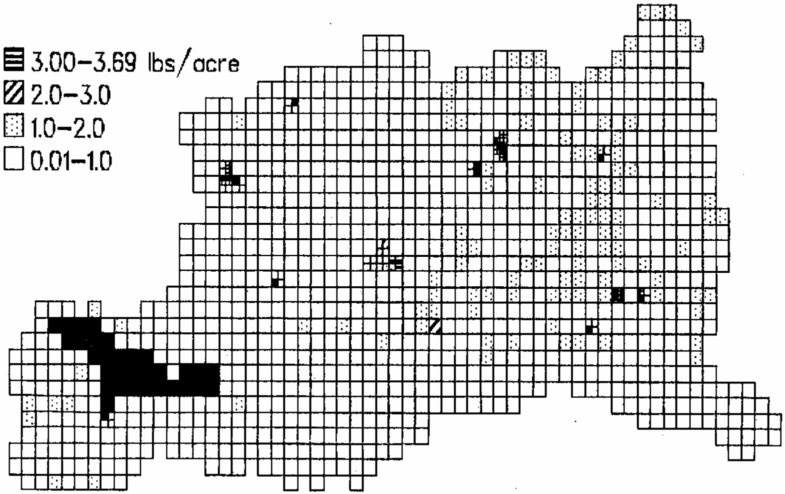


Figure 4-10. Sediment nitrogen yields for the modeled storm event.

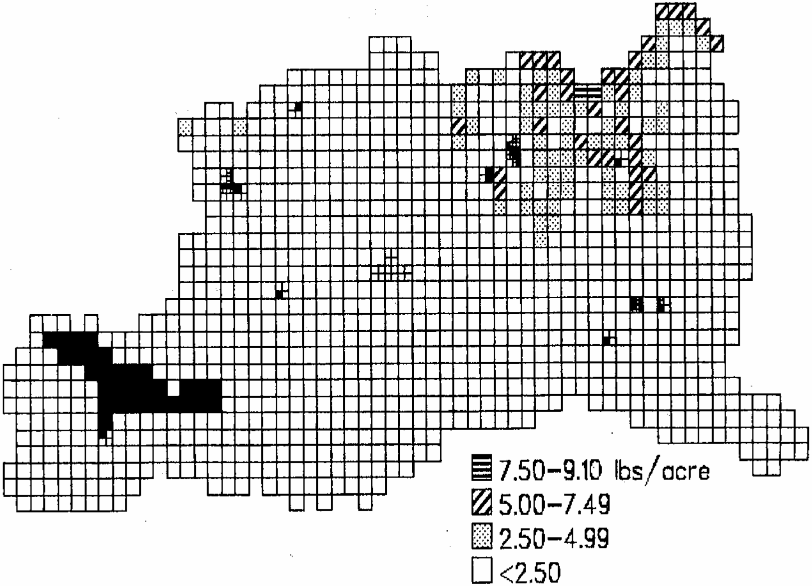


Figure 4-11. Soluble nitrogen yields for the modeled storm event.

Table 4-3. AGNPS Summary Data for Watershed Streams.

CELL NUMBER	DRAINAGE AREA (ac)	SEDIMENT YIELD (tons)	RUNOFF VOLUME (m3)	SEDIMENT PHOS (lbs)	SOLUBLE PHOS (lbs)
436	1200	50.8	187570	156	228
437	4160	294.6	774300	790	2330
599	1400	64.4	305212	210	196
600	6720	378.9	1575585	1075	2621
704	760	57.6	141459	152	53
739	4600	126.1	785242	460	138
742	1880	61.8	243594	188	19
748	3860	217	718462	617	270
756	10360	453.6	2429026	1347	725
786	960	21.8	201391	77	10
843	36360	1040.7	8861553	3272	4000
845	2760	74.8	578998	276	28
1031	1120	33.6	153182	112	22

Locator Key

Cell 436 - Big Thunder Creek
Cell 437 - N. Fork Beanblossom above Cell 436
Cell 599 - Dunnaway Creek
Cell 600 - N. Fork Beanblossom
Cell 704 - Hoppers Branch
Cell 739 - Bear Creek
Cell 742 - Brier Creek
Cell 748 - Lick Creek
Cell 756 - S. Fork Beanblossom
Cell 786 - Possom Trot Creek
Cell 843 - Beanblossom Creek mouth
Cell 845 - Plum Creek
Cell 1031 - Shuffle Creek

cell. For example, Cell 843 is the mouth of Beanblossom Creek and this cell receives drainage from all the watershed area upstream from that point (36,360 acres total). The greatest amount of runoff, sediments and nutrients are contributed by the South Fork Beanblossom Creek and the North Fork Beanblossom Creek above Big Thunder Creek (see also Figure 2-4). The largest contribution of sediments from a sub-watershed comes from Bear Creek (Cell 437) while Lick Creek (Cell 748) contributes the most nutrients.

Because larger watershed would likely export more sediments and nutrients than smaller watersheds, we calculated the contribution per area drained for these constituents. The largest areal sediment yields come from the Hoppers Branch and North Fork Beanblossom Creek (Figure 4-12). These watersheds are dominated by agricultural land uses and are characterized by broad ridgetops and valley bottoms with steep slopes in-between. The smallest sediment yields are contributed by the Big Thunder Creek, Possum Trot Creek, Bear Creek and Plum Creek watersheds.

The areal sediment phosphorus patterns follow those for areal soil erosion, as expected (Figure 4-13). The highest predicted soluble phosphorus areal yields are from the North Fork Beanblossom Creek, Big Thunder Creek and Dunnaway Creek (Figure 4-14). High soluble phosphorus losses in Lake Lemon's watershed are associated with agricultural lands with high runoff rates. The model predicted low soluble phosphorus areal yields for Brier, Possum Trot, Plum and Shuffle creeks.

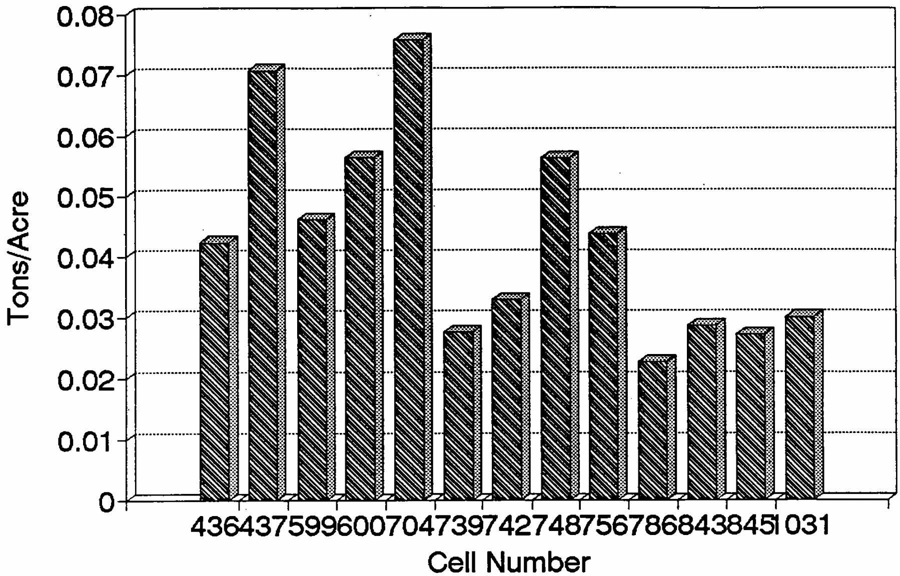
<u>Use of AGNPS Results</u>

How can we use the AGNPS results? AGNPS calculates rates of runoff, erosion, and nutrient export for 40-acre cells based on generalized conditions (data input) within each cell using standard equations governing these processes. The results likely represent worst case conditions. The actual yield could differ significantly and depends on specific use and management of the land. For example, existing fertilizer management practices on the agricultural lands could reduce actual nutrient losses below those predicted by AGNPS. Likewise, AGNPS could underestimate actual soil or nutrient losses if landowners use poor land management practices.

AGNPS results are best used to compare the relative yields from different cells or sub-watersheds. By considering yields in one area relative to others, watershed problem areas can be identified. The magnitude of the numerical output, expressed as lbs/acre for example, is less useful when interpreted by itself. The yields given in the output are for a single storm event of known amount and intensity. They cannot be added up to estimate a total annual yield rate.

AGNPS identifies areas of potential concern. It is up to local officials, working with the Division of Soil Conservation and the Soil Conservation Service, to field check cells which AGNPS identifies as potential sources of nonpoint source pollution. If the model's output is verified, then nonpoint source management practices can be recommended to address specific problems (see Section 6.0).

Relative Sediment Yields:Sub-Watersheds

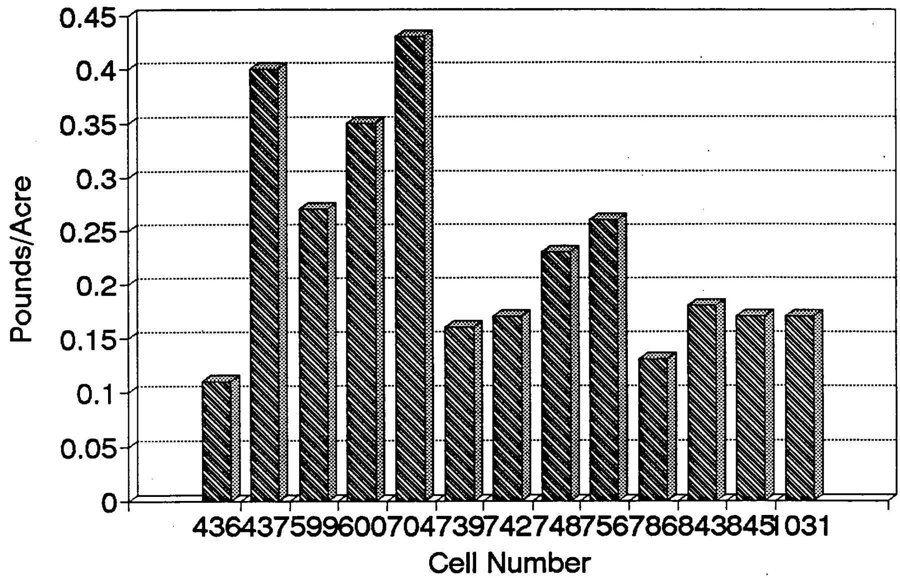


Locator Key

Cell 436 - Big Thunder Creek	Cell 748 - Lick Creek
Cell 437 - N. Fork Beanblossom above Cell 436	Cell 756 - S. Fork Beanblossom
Cell 599 - Dunnaway Creek	Cell 786 - Possom Trot Creek
Cell 600 - N. Fork Beanblossom	Cell 843 - Beanblossom Creek mouth
Cell 704 - Hoppers Branch	Cell 845 - Plum Creek
Cell 739 - Bear Creek	Cell 1031 - Shuffle Creek
Cell 742 - Brier Creek	

Figure 4-12

Sediment P Yields from Sub-Watersheds



Locator Key

Cell 436 - Big Thunder Creek	Cell 748 - Lick Creek
Cell 437 - N. Fork Beanblossom above Cell 436	Cell 756 - S. Fork Beanblossom
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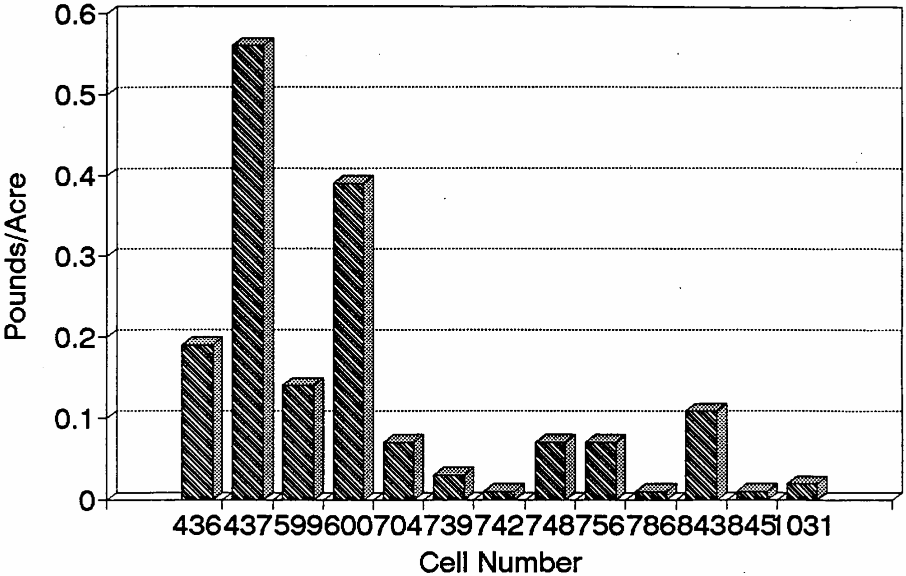
Cell 704 - Hoppers Branch	Cell 845 - Plum Creek
Cell 739 - Bear Creek	Cell 1031 - Shuffle Creek
Cell 742 - Brier Creek	

Figure 4-13

Soluble P Yields from Sub-Watersheds



Locator Key

Cell 436 - Big Thunder Creek	Cell 748 - Lick Creek
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Cell 739 - Bear Creek	Cell 1031 - Shuffle Creek
Cell 742 - Brier Creek	

Figure 4-14

5.0 SEDIMENT AND NUTRIENT CONTROL

The results of the AGNPS modeling suggest that human and land use activities in Lake Lemon's 182 km^2 (70 mi^2) watershed are the primary sources of sediment and nutrient loadings to the lake. This is consistent with Willett (1980) who estimated that 70 percent of all sediment pollution nationally is caused by human activities. Although it is unrealistic to expect that all nonpoint source pollution can be eliminated, Best Management Practices (BMPs) can be used to prevent or reduce nonpoint source pollution. While BMPs were developed originally for agricultural pollution control, they have also been adopted for forestry and urban nonpoint source control as well.

The degree to which BMPs should be used depends upon many factors including soils, topography and the individual farm or land management operation. It is not practical to select a specific set of BMPs without knowledge of these factors. Making these specific selections for each site in the Lake Lemon watershed is beyond the scope of this project.

Therefore, in the following section, we give an overview of BMPs and other practices for controlling agricultural and urban sources of nutrients and sediments. We refer the reader to a number of excellent publications for more detailed information on the subject. We have used these publications to prepare the material following. They include: Soil Conservation Service (1983); Garman et al. (1986); Moore and Thornton (1988); and UWEX (1989).

5.1 AGRICULTURAL BMPs

The following practices are designed to control the loss of both soils and nutrients from agricultural lands. Practices that prevent soil erosion are also important in controlling particulate forms of nutrients. Soluble (or dissolved) nutrients are controlled along with runoff.

5.1.1 Conservation Tillage

Conservation tillage is a farming practice that leaves at least 30 percent of the crop stalks or stems and roots intact in the field after harvest. Its purpose is to enhance water infiltration, reduce water runoff and soil erosion compared to conventional tillage where the topsoil is mixed and turned over by a plow. This practice can reduce sediment loss by 40–90 percent, particulate phosphorus loss by 25–70 percent and dissolved phosphorus loss by 25–42 percent.

5.1.2 Contour Stripcropping

In this practice, the farmer plows across the slope of the land. Strips of close growing crops or meadow grasses are planted between strips of row crops like corn or soybeans. Contour stripcropping on 2 – 7 percent slopes can reduce soil erosion by 75% compared to plowing up and down the slope. Particulate and dissolved nutrient losses can be reduced by up to 50 percent.

5.1.3 Crop Rotation

Crop rotation involves periodically changing the crops grown on a particular field. Rotations are most effective if row crops are alternated with pasture in two to four year rotations. Pasture rotations improve soil structure, increase organic matter content and increase soil porosity relative to continuous row cropping. Nutrient losses can be reduced by 50 percent or more when pasture rotation is used.

5.1.4 Grassed Waterways

Grassed waterways are natural or constructed waterways or outlets, shaped or graded, and established in suitable vegetation to provide for removal of excess surface water. These vegetated channels reduce gully erosion, increase water infiltration, and trap sediment and nutrients. Sediment losses can be reduced by 60–80 percent in the grassed waterway.

5.1.5 Buffer Strips

Buffer strips are strips of grass or other close-growing vegetation intended to remove sediment or other pollutants from sheet flow runoff. They are usually placed along streams or lake shores, around feedlots, and at the edges of fields to prevent pollutant transport from human-disturbed areas. Sediment reductions of 30–50 percent are possible for a properly designed buffer strip. When used to control runoff from feedlots, sediments can be reduced by up to 80 percent and nutrients reduced by 60–70 percent.

5.1.6 Animal Waste Management

This is a practice where animal wastes are temporarily held in waste storage structures or basins until they can be safely utilized or disposed. Outside storage areas should be covered to prevent water accumulation and runoff. Once fields have thawed in the spring, the stored wastes can be applied and the nutrients contained within them can infiltrate into the soil. Animal wastes should <u>not</u> be applied to frozen fields in the winter. Runoff over the frozen soil can transport the wastes and their nutrients off site.

In feedlots, barnyards, or other areas where animals (and their wastes) are concentrated, a shallow basin can be constructed to collect runoff and liquid wastes, rather than let these materials run off the site.

Livestock should be kept off streambanks and lakeshores where they can erode the banks and deposit wastes directly into the water. Streambanks and lakeshores should be fenced off to prevent these problems. Livestock access for watering and crossing can be provided by a stabilized crossing area with gravel or concrete bottom.

5.1.7 Fertilizer Management

Fertilizer management is a practice used to decrease the availability of nutrients to runoff while providing optimum amounts of plant nutrients for crop production. It is the most important practice in controlling water pollution by nutrients from agricultural lands. Soil tests are probably the most important guide to the proper use of fertilizers. These tests, combined with information about soil type, previous cropping, and the anticipated soil moisture level, should be used to estimate fertilizer requirements. Apply fertilizer as close to the time of plant demand as possible, especially nitrogen fertilizers. If practical, all fertilizer should be incorporated into the soil to reduce loss by volatilization and surface runoff.

5.2 FORESTRY BMPs

Despite the large percentage of forest land in the watershed, commercial timber harvesting is limited. Where timber harvesting does occur, forestry BMPs should be used. Some of these are listed below (W.Va Department of Agriculture, undated).

5.2.1 Planning

The landowner and logger should mutually spend time planning and laying out roads and landings to prevent potential problems. This includes fitting the roads to the lay of the land and keeping grades low. Well planned and properly located roads can be a great asset to the landowner's property. Permanent roads permit access for fire protection, firewood cutting, future timber management, and harvesting.

5.2.2 Stream Buffers

You should plan and build roads and landings at least 100 feet from streams and ponds. Equipment should be kept out of streams. A filterstrip of vegetation should be left along the stream.

5.2.3 Stream Crossings

When a stream must be crossed, a culvert or bridge should be used; crossing should be at a right angle, and the approaching reads should not drain water into the stream.

5.2.4 Drainage

The logger should use ditches, culverts, dips, and grade breaks, and log in favorable weather when possible. These drainage structures need to be maintained during operation to keep them working. To prevent water from washing down long stretches of road or standing in landings or dips, the logger should inspect ditches, culverts, etc., periodically to make sure they are effective. If muddy water is noticed entering a stream, or if there is a possibility of this, steps need to be taken to correct the problem.

5.2.5 Site Closure

Retire logging roads as soon as they are not needed. Do not wait until the whole job is completed. For example:

1. Smooth and grade landings and main haul road for drainage, utility and appearance.
2. Clean ditches and culverts which are permanent.
3. Pull out temporary culverts and bridges and regrade cross-ditch. All natural drainages should flow across, not down, the road.
4. Plant a cover crop on all exposed soil using lime, fertilizer, mulch and seed such as Kentucky 31 fescue (grass) as needed.
5. Gate road or use a deep trench to eliminate vehicle access.
6. Plan for future maintenance - the cleaning or repairing of water control structures.
7. Install water bars or water-breaks at recommended intervals. Rocks, brush and logging debris can often be used as water retardants on skid trails.

5.3 URBAN BMPs

The urbanization of watersheds can have important impacts on both the quantity and quality of stormwater runoff. For example, paved surfaces prevent the infiltration of precipitation resulting in a greater volume and velocity of runoff. Auto and bus exhaust, construction activities, and residential fertilizers are all urban sources of pollutants that can adversely affect lakes and receiving streams. In a study of urban runoff in Bellevue, Washington, Pitt (1985) calculated annual mass yields of 183 lbs/acre of total solids, 80 lbs/acre of chemical oxygen demand, 1.6 lbs/acre of total nitrogen and 0.4 lbs/acre of total phosphorus. Residential lawns contributed 83 percent of the total solids and streets contributed 45 percent of the COD, 32 percent of the phosphorus and 31 percent of the total nitrogen. Driveways, parking lots and residential lawns were the next highest sources of COD, phosphorus and nitrogen in the runoff.

The Urban Planning Development Guide prepared by the Hoosier Heartland RC&D Council (1985) is an essential reference for all urban nonpoint source problems and management practices. Readers are encouraged to acquire a copy of this guide.

5.3.1 Stormwater Management

The traditional approach to stormwater management was to use curbs, gutters and underground pipes to remove stormwater as quickly as possible to minimize local flooding. However, while these measures may relieve flooding of upstream areas, they contribute to the flooding and erosion of downstream areas that receive the rerouted stormwater. Recommended objectives and approaches to stormwater management have now expanded to include the mitigation of downstream flooding by:

1. Reducing the amounts of impervious surfaces such as driveways and roads.

2. Temporary stormwater storage in streets and parking lots, in grassy areas, in percolation trenches, and in ponds located both on and off the site.

3. Using grassed swales (vegetated channels) instead of curb and gutter. This costs less ($1-2/foot vs. $40/ft) and can remove up to 90 percent of total solids and 70 percent of phosphorus.

4. Using catch basins at the entrance to gutters to trap sediments.

5. Using sedimentation basins to detain stormwater and trap sediments and nutrients. Well designed wet sedimentation basins can remove 70-90 percent of solids and 60-70 percent of nutrients from stormwater runoff (Pitt, 1989). Basins need at least six feet of permanent standing water to protect the trapped sediments from scouring, to minimize rooted plant growth and to increase winter survival of fish. Correct basin side slopes are important to improve safety and to minimize rooted plant growth (Jones and O'Reilly, 1986). The size of wet sedimentation basins should be approximately 0.5 percent of the size of the watershed which drains into it.

5.3.2 Construction Sites

Urban construction activities account for ten percent (or 500 million tons) of all sediments that reach U.S. waters each year. This is equal to the combined contributions of forestry, mining, industrial and commercial activities (Willett, 1980). In urban areas, construction activities may account for 50 percent of the sediment load. Construction sites have an erosion rate of approximately 10 to 200 tons per acre per year, a rate that is about 2 to 100 times that of croplands (Pitt, 1989). This high erosion rate means that even a small construction project may have a significant detrimental effect on local water bodies. For example, for a quarter-acre homesite cleared of vegetation, up to five tons of soil (one-half a truck-load) erodes from the site every month (Wisconsin DNR, 1982).

The following no-cost and low-cost practices can be useful in preventing erosion from construction sites (Wisconsin DNR, 1982):

1. Plan your construction activities so that the soil is disturbed a minimal amount of time. For example, plan to install gas pipelines, sewer laterals, and other utilities at close time intervals.

2. Leave grass, trees, and shrubs in place wherever you can. The more vegetation, the less sediment-laden water leaves your site.

3. When you excavate the basement, pile the soil away from stormsewer drains - in the back or side yard area, for example. Once you backfill around the basement, remove any excess soil from the site.

4. Park cars and trucks on the street not on the site. You'll keep the soil less compacted and more water-absorbent, and you'll keep mud from being tracked onto the street.

5. Arrange to have the street cleaned regularly while you're building to remove sediment that preventative measures failed to keep off the street.

6. Soon after you start construction, install a gravel driveway and encourage cars and trucks to use only this route on your site. Later, you can install the permanent driveway over the gravel.

7. Build a berm to divert rainwater away from steep slopes or other highly erodible areas.

8. Install straw bales or filter fences along curbs to filter rainwater before it reaches the gutter and stormsewer drains.

9. Seed and mulch, or sod your site as soon as you complete outside construction. You'll control erosion, and - if you're building for a prospective buyer - you'll increase the lot's salability by making it more attractive.

10. If you can't seed and mulch the entire lot, cover any critical areas with a temporary protective material, such as filter fabric or netting. Later, you can remove the cover long enough to install utility lines.

11. Use roof downspout extenders and sump pump drain tubes to funnel water away from exposed soils and directly to the curb and storm-sewer. After site is vegetated, downspout extenders and drain tubes should outlet to the vegetated area to maximize infiltration.

While these practices are useful on individual lots, they are no substitute for an area-wide erosion control or storm drainage control regulation. The Highway Extension and Research Project has published a model erosion control ordinance (HERPICC, 1989). This along with the Urban Development Planning Guide prepared by the Hoosier Heartland RC&D Council, Inc (1985) are indispensable references for communities developing their own erosion control regulations. Remember, the most complete ordinance is meaningless unless it is enforced. Funds and personnel must be made available for active enforcement.

5.3.3 Fertilizer Management

Lawn and garden fertilizers can be important sources of nutrients to lakes, especially when applied to lakeshore property. Application rates should be sized to what the lawn or garden needs. Excess fertilizer can wash away, possible into a nearby stream or lake. This wastes money and contributes to nutrient enrichment of surface waters. Because grass has a high need for nitrogen, and because phosphorus is the nutrient which most often causes algae blooms in lakes, use lawn fertilizer formulas low in phosphorus. For example, fertilizers should contain less that 1/2 percent phosphorus if in liquid form or 3 percent if in granular form. It is best to have the soil tested *before* applying fertilizer on a lawn or garden. Contact your county extension agent for instructions or a simple kit for taking a soil sample. Soil samples can be mailed to testing laboratories for analysis for a modest fee.

Follow these guidelines for wise fertilizer management on the lakeshore:

1. Use fertilizers containing less than 1/2 percent phosphorus if in liquid form or 3 percent if in granular form.

2. Use organic fertilizers whenever possible. They release their nutrients slowly as the plants need them.

3. Make and use your own compost on your garden. It serves as a valuable weed-controlling mulch and an organic fertilizer. By using grass clippings and leaves in compost, they won't wash into the lake either.

4. Make sure that your soil is rich in organic matter. Nutrients in fertilizers stick to organic matter until needed by plants.

5. Do not apply fertilizers to your lawn or garden between November 15 and April 15. The plants can't use fertilizers during this period and the ground may be frozen, allowing the fertilizer to run off into the lake.

6. Leave a 25 foot fertilizer-free buffer along the lakeshore.

5.4 SHORELINE AND STREAMBANK PROTECTION

Few things are a bigger eyesore and problem for lakeshore property owners than an ugly, eroding shoreline. There are a variety of lake shoreline and streambank protection practices designed to stabilize and protect these areas against scour and erosion from forces such as wave action, ice action, seepage, and runoff from upland areas. Shoreline stabilization methods fall into two broad areas: nonstructural (vegetation or beach sloping) and structural (flexible structures such as rip-rap and rigid structures like seawalls) (McComas, 1986).

5.4.1 Shoreline Revegetation

Vegetation effectively controls runoff erosion on slopes or banks leading down to the water's edge; however, vegetation is generally ineffective against direct wave action or seepage-caused bank slumping. The type of vegetation to establish depends on the steepness of the slope. If the slope angle is steeper than 1:1 (i.e., 1 foot horizontal for every 1 foot vertical), the soil is probably unstable and the possibility of establishing protective vegetative cover is slight (McComas, 1986). Steep slopes should be re-graded to a 2:1 slope or flatter (SCS, 1989). All materials excavated from sloped banks may be placed on the bank, leveled, and seeded to prevent erosion during high water or hauled to other areas for use. Do not place excavated material into the lake or stream, or form barriers which interfere with runoff entering natural channels.

On long, steep slopes leading down to the water's edge where regrading to a gentler slope is too impractical, consider slope modifications which will allow vegetation to become established (Figure 5-1). Slope terracing provides horizontal steps in which to plant vegetation. Contour wattles are bundles of live willow cuttings anchored into the bluff face with either construction or live willow cuttings (Michigan Sea Grant Program, 1988). The bundles trap surface runoff and soil particles and lets vegetation become established.

Once an appropriate slope is created, seed or plant the bare soil immediately. Use erosion control mats of nylon mesh or wood excelsior on top of the soil to assist in seed germination, seedling protection, and erosion control. Time your work to coincide with optimal planting times. Grasses can be planted in the spring or fall while woody plants should be planted when they are dormant. A protective grass cover can be established within one year. Slopes should be 3:1 or flatter to facilitate mowing. Herbaceous ground covers, shrubs and trees may take several years to become established. Ground covers are useful when mowing isn't desired. When using trees or shrubs to stabilize banks, plant grasses initially until the woody vegetation becomes established. A guideline for vegetative covers is presented in Table 5-1.

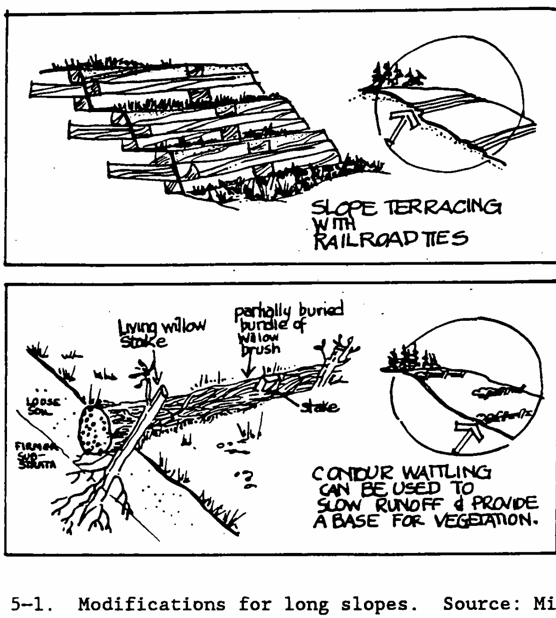


Figure 5-1. Modifications for long slopes. Source: Michigan Sea Grant Program (1988).

TABLE 5-1. Vegetation for Lakeshore and Streambank Slopes. Adapted from: McComas (1986).

VEGETATION	>3:1 SLOPE	>1:1 SLOPE
Grasses	Kentucky bluegrass[1]	red fescue[1] switchgrass big bluestem little bluestem
Ground Covers	(same as >1:1 slope)	goutweed bearberry crown vetch[1] memorial rose creeping juniper purple wintercreeper
Shrubs	(same as >1:1 slope)	red chokecherry gray dogwood sumac common juniper common witch hazel border privet snowberry tatarian honeysuckle[1]
Trees	(same as >1:1 slope)	red maple silver maple paper birch[1] white ash white pine black cherry

[1]non-native species that the Indiana DNR considers potentially invasive.

If regrading steep, eroded lakeshore slopes isn't possible, dormant woody plant cuttings can be used to vegetatively stabilize shorelines. The Illinois Water Survey has successfully stabilized eight-foot, 1:1 slope eroded streambanks with dormant willow posts (Illinois Resources, 1990; SCS, 1990). The willow post method uses 7-12-foot posts (one-half to three inches in diameter) that are placed in holes driven into the streambank (Figure 5-2). The willow posts are placed about four feet apart in offset rows. Within a few months, the posts regrow root systems and branches. Post length will vary with the depth to saturated soil and the bank elevation. About 40% of the post length must be buried in the bank, with the bottom of the post in the saturated zone. The Soil Conservation Service has approved the willow post

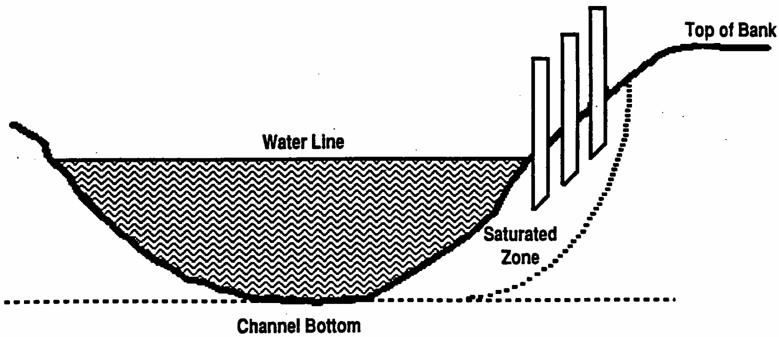


Figure 5-2. Willow post technique for steep streambanks and lakeshores.

technique for cost sharing funds. The SCS (1990) estimates that the average cost of regrading a 12 foot high bank to 1:1 slope is $77 per 100 foot length, and the cost per hole is $2.40 per 6 foot post and $2.90 per 9 foot post. Labor to cut and transport the posts can be calculated at 10 posts per person per hour.

5.4.2 Littoral Zone Revegetation

Diverse, moderately dense stands of aquatic plants are desirable in a lake's littoral zone. Emergent aquatic plant communities protect the shoreline from erosion by dampening the force of waves and stabilizing shoreline soils. Vegetation can also provide screening for the lakeshore homeowner and buffer noise from motor boats. Many species of aquatic plants, such as the white water lily and pickerelweed, are aesthetically pleasing because they have showy flowers or interesting shapes. Aquatic vegetation also provides fish habitat and spawning sites, waterfowl cover and food, and habitat for aquatic insects. For example, sedges (*Carex* spp.) become spawning beds for northern pike in spring, wild rice beds (*Zizania aquatica*) attract shorebirds in summer, and wild celery (*Vallisneria americana*) develops tubers that attract canvasbacks in fall and is one of the finest fish food and cover plants (Engel, 1988). Table 5-2 lists the positive attributes of some aquatic plant species.

A management goal should be to produce stable, diverse, moderately dense aquatic plant communities containing high percentages of species with desirable attributes (Nichols, 1986). This technique has been used successfully to enhance the benefits of aquatic vegetation in several Wisconsin lakes (Engel, 1984; Nichols, 1986; Engel, 1988). For example, 15,900 tubers of nine emergent and two submergent species were planted along the lakeshore and constructed islands in Elk Creek Lake, a 54-acre Wisconsin impoundment, to stabilize slopes, improve water clarity, and attract waterfowl (Figure 5-3). Species with rapid growth rates, high productivity, and long growing seasons may interfere with water uses and should be avoided.

Plantings can increase the population of an aquatic plant species or the area of cover. Planting is labor intensive and may be expensive. Plant propagules must be collected or purchased from a commercial source. They then have to be weighted or placed directly in bottom sediment (Nichols, 1986). For example, tubers of wild celery and sago pondweed should be weighted with a 16 penny nail attached by a rubber band or sunk in mesh bags containing stones (Engel, 1988). Tubers and roots should be planted in the early spring. For some species that produce seed, the seed can be broadcast in the fall. An alternative method is to pack the seeds in mud balls before sowing.

Table 5-3 lists some rooted plants to grow in midwestern lakes needing habitat. Bulrushes (*Scirpus spp.*) are among the best emersed plants as far as withstanding the physical action of waves and currents. By buffering wind and wave action, this species allows other aquatic plants to gain a foothold and grow. Reed canary grass (*Phalaris arundinacea*) has deeply and intertwined root systems that binds shoreline soil well and they provide excellent cover for aquatic insects, fish fry, and waterfowl. Eurasian species of this plant are invasive and should be avoided. The extensive root system of Sago pond weed (*Potamogeton pectinatus*) makes it carp-resistant and it is proclaimed as the best all-around duck food in North America (Wildlife Nurseries, 1990).

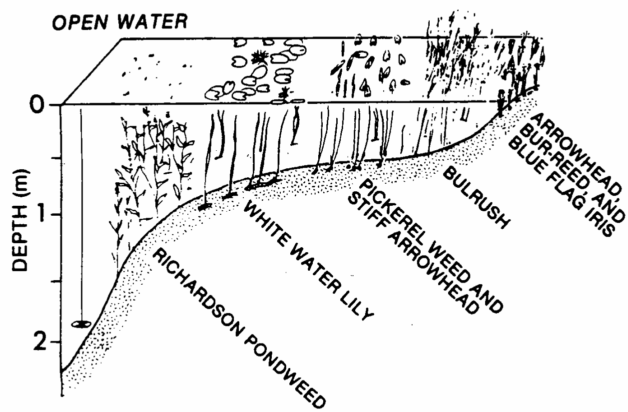


Figure 5-3. Revegetation plan for the shore of Elk Creek Lake, Wisconsin. Source: Engel (1988).

TABLE 5-2. Aquatic Plant Attributes.

	NUISANCE RANK[1]	WATERFOWL FOOD VALUE[2]	POSITIVE AESTHETIC VALUE	OTHER
Emergent species				
Acorus calamus		S	X	human food[3]
Clyceria borealis		F		
Leersia oryzoides		F–G		
Pontederia cordata		S–F	X	
Sagittaria spp.		F	X	human food[3] shoreline protection
Scirpus cyperinus				shoreline protection
Scirpus validus		S–F		
Sparganium chlorocarpum		F	X	
Typha latifolia				food for aquatic fur bearers and humans[3] shoreline protection
Zizania aquatica		E	X	human food[3]
Floating-leaved species				
Brasenia schreberi	L	F–E	X	
Lemna minor		F–E		
Nelumbo lutea	L		X	
Nuphar spp.	L	F	X	
Nymphaea odorata	L	S	X	
Nymphaea tuberosa	L	S	X	
Polygonum coccineum		G–E		
Polygonum natans		G–E		
Wolfia spp.		F		
Submerged species				
Ceratophyllum demersum	R	S–F		good macroinvertebrate habitat[4]
Chara vulgaris	L	G–E		
Eleocharis acicularis		F–G		suppresses nuisance macrophytes
Elodea canadensis	R	S		
Heteranthera spp.				good macroinvertebrate habitat[4]
Myriophyllum spp.	R	S–F		good macroinvertebrate habitat[5]
Najas flexilis	L	E		
Najas quadalupensis	L	E		
Najas minor	L			
Potamogeton amplifolius		F		
P. crispus	R			good macroinvertebrate habitat[5]
P. foliosus		F–G		
P. gramineus		F–G		
P. natans		F–G		
P. pectinatus	L	E		
P. pusillus		F–G		
P. richardsonii		G		
P. strictifolius		F		
P. zosteriformes		F		
Ruppia sp.		E		
Utricularia vulgaris	L			
Vallisneria americana	L	E		
Zanichellia sp.	L	F–G		

[1] After Trudeau, 1982. R = regional problem, L = local problem
[2] After Carlson and Moyle, 1968. S = slight, F = fair, G = good, E = excellent
[3] Fernald et al. 1958
[4] Krull, 1970
[5] Krecker, 1939

Source: Nichols (1986).

TABLE 5-3. Some Rooted Plants to Grow in Midwestern Lakes Needing Habitat.

Common name	Scientific name
Emergent species: plant rootstock in ankle-deep water.	
Common arrowhead	*Sagittaria latifolia*
Pickerelweed	*Pontederia cordata*
Slender spikerush	*Eleocharis acicularis*
Sweetflag	*Acornia calamus*
Reed canary grass	*Phalaris arundinacea*
Emergent species: plant rootstock or seed no greater than waist deep.	
Hardstem bulrush	*Scirpus acutus*
Common cattail	*Typha latifolia*
Sedge	*Carex spp.*
*Wild rice	*Zizania aquatica*
Floating-leaved species: plant rhizome no deeper than about 0.9 m (3 ft.).	
American lotus	*Nelumbo lutea*
White water lily	*Nuphar advena*
Yellow water lily	*Nymphaea tuberosa*
Submergent species: plant seed, cutting with leaf node, or whole plant no deeper than 10% of surface light.	
Broad-leaved pondweeds	*Potamogeton amplifolius, illinoensis, natans, richardsonii*
Narrow-leaved pondweeds	*Potamogeton berchtoldii, foliosus, pectinatus*
**Wild celery	*Vallisneria americana*

*Plant seeds only.
**Plant tubers or whole plant only.

Source: Engel (pers comm); Wildlife Nurseries (1990)

Two sources of aquatic plants and seeds in the midwest are:

Wildlife Nurseries
P.O. Box 2724
Oshkosh, Wisconsin 54903

Country Wetland Nursery, Ltd.
Box 126
Muskego, Wisconsin 53150

Prices vary depending on the species and whether tubers or seed are planted. For example, the following are current costs for 1,000 tubers, which will plant one acre at the recommended planting density: Sago pondweed ($130), wild celery ($140), and hardstem bulrush ($160). Enough reed canary grass seed to plant one acre costs $46.80 (at 12 lbs. per acre). Experience in Florida suggests that aquascaping projects will cost approximately $2,000 to $10,000 per acre (Miller, 1988). However, these costs can be reduced greatly by using volunteers to plant the tubers and seed.

5.4.3 Beach Sloping

Beach sloping takes advantage of the ability of semifluid sands to dissipate the energy of the breaking and receding waves (McComas, 1986). A typical cross section is shown in Figure 5-4. The final slope of the beach line is based on the size of the material used. Design considerations include:

1. Minimum thickness of the sand blanket is one foot.

2. Extend the blanket to a water depth two times the design wave height.

3. Extend the beach blanket the distance equal to the computed runup plus one foot.

4. The size of the material used and the final slope should be determined by a professional engineer.

One problem with beach sloping is that a strong along-shore current may erode the blanket material. Periodic replenishment will be necessary in this case.

5.4.4 Structural Methods

Riprap is a flexible structure constructed of stone and gravel which is designed to protect steeper (slope > 1:1) shorelines from wave action, ice action and slumping due to seepage. The riprap is flexible in that it will give slightly under certain conditions. This improves its ability to dissipate wave energy. Riprapping involves more than simply dumping rocks on the shoreline. Filter fabric or graded stone must be used on the soil base to prevent soil from moving through the stone and undercutting it. The toe

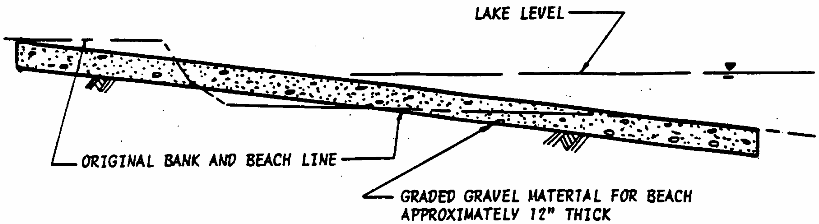


Figure 5-4. Cross section of beach sloping. Source: McComas (1986).

(bottom) of the riprap must be protected by burying it at least three feet below the sediment surface (Figure 5-5). The size of the largest stones used depends on the design wave height. See SCS Standards and Specifications 580 entitled, "Streambank and Shoreline Protection" (SCS, 1989) or your county SCS agent for more information.

Seawalls, bulkheads, and retaining walls are rigid structures used where steep banks prohibit the sloping forms of protection. Seawalls primarily prevent land masses from sliding from the shore into the water and secondarily prevent wave action from damaging the shoreline. Seawalls do not dissipate wave energy but rather, redirect the wave energy away from the shore. This often erodes the shoreline at the base of the wall and may affect the slope of the lake bottom some distance from shore. The cumulative effect of too many seawalls around a lake can be devastating to aquatic species.

The placement of riprap and seawalls is best left to the professional. *The use of both of these methods requires a permit from the Indiana Department of Natural Resources and may require a 404 Permit from the U.S. Army Corps of Engineers. These agencies must be contacted before any material is placed or deposited in a stream channel or on a lake bed.*

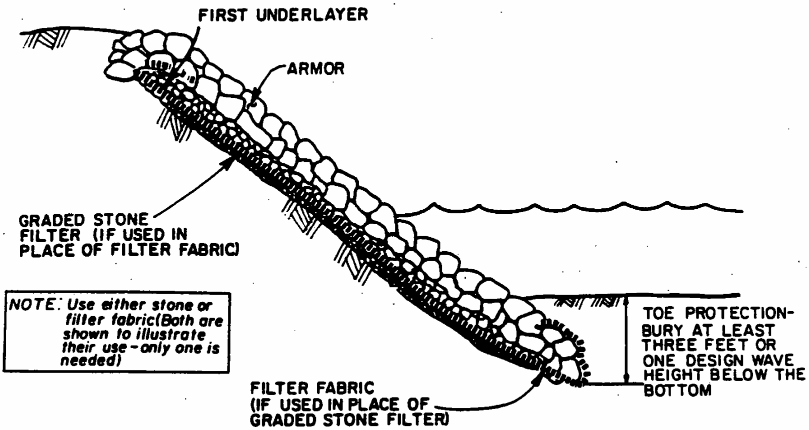


Figure 5-5. Cross section of a riprapped shore.
Source: McComas (1986).

5.4.5 Streambank Fencing

Cattle, hogs and other farm animals can destroy streambank structure and vegetative cover when they walk down or along streambanks to get water. This leads to serious erosion and sediment transport to downstream areas. Farm animals should not have unrestricted access to streams. Streambank fencing can be used to protect banks from farm animals. Stabilized crossings or access points should be constructed to allow farm animals access to the water if there are no other watering alternatives.

5.5 WETLANDS TREATMENT

5.5.1 Purpose

Wetlands are emerging as a low-cost, efficient treatment system for a wide variety of wastewaters, including: municipal wastewater, acid mine drainage, urban runoff and more recently, non-point source pollution (Watson et al., 1989). For example, the Indiana Department of Natural Resources T by 2000 Lake Enhancement Program has supported the use of constructed and reconstructed wetlands to protect lakes from sediment and nutrient inputs from their watersheds. Under this program, wetland treatment systems have been constructed at Lake Maxinkuckee and Koontz Lake in Marshall County and at Prides Creek Reservoir in Pike County. Treatment efficiencies vary with design, vegetation used, soil conditions, and loading rates, but removal rates of 95 percent for sediment, 90 percent for total phosphorus, and 75 percent for total nitrogen are reported (Livingston, 1989).

5.5.2 Design Considerations

There are several important design considerations to consider for enhancing the sediment and nutrient removal efficiencies of constructed or enhanced wetlands. These include:

1. Sizing the wetland to the drainage area.
2. Reducing water velocities through the system.
3. Maintain optimal water levels.
4. Pretreatment to remove sediments.

Wetland surface area must be sized to meet the expected volume of water it receives. Design features should maximize runoff residence time which, in turn, enhances contact with wetland sediments, vegetation and microorganisms. Maryland's urban stormwater regulations suggest a designed detention time of 24 hours for the one-year storm event (Livingston, 1989). This will enhance pollutant removal and provide storage volume recovery between storms. If extended detention is not possible, then the wetland surface area should be a minimum of 3 percent of the contributing drainage area. Extended detention can be provided by incorporating a sedimentation basin into the wetland design.

High water velocities through wetlands can reduce soil and plant removal efficiencies and may even wash out rooted vegetation. Mechanical stress due to high water velocities can cause changes in vegetation leaf form, reduction in plant growth and may shift biomass from the leaves to the roots (Guntenspergen et al., 1989).

The wetland hydroperiod must be consistent with the needs of the vegetation used. Hydroperiod is the depth and duration of inundation measured over an annual wet or dry cycle. The proper hydroperiod determines the form, nature, and function of the wetland (Livingston, 1989). Water depth and inundation period can change the vigor and species composition of the wetland plant community. This can have detrimental impacts on the wetland or its nonpoint pollutant removal.

Finally, many wetland treatment systems incorporate presedimentation basins to remove some of the sediment load before it reaches the wetland. Sediment accumulation within the wetland can change plant species composition or even bury rooted vegetation. Pretreatment can not only enhance the functioning of the wetland but also extend its usable lifetime.

5.6 IN-LAKE TREATMENT

There are numerous in-lake methods available to combat the effects of excessive sediments, nutrients and macrophytes in lakes. Some of these include:

1. Dredging
2. Nutrient inactivation/precipitation
3. Dilution/flushing
4. Biotic harvesting

5. Selective discharge
6. Sediment exposure and desiccation
7. Lake bottom sealing
8. Biological controls

Each of these methods has been discussed thoroughly in the original Phase I Report (Zogorski et al., 1986) and will not be duplicated here. Refer to the original report for more information.

6.0 RECOMMENDATIONS

6.1 GOALS

Lake enhancement efforts on Lake Lemon must focus on the lake's watershed. The watershed's large size and relatively steep topography provides for high hydraulic loadings to the lake (flushing rate = 5 volumes per year), despite the extensive forest cover. During particularly heavy rainstorms, Lake Lemon has noticeable flow within it, much like a large river. This rapid response to storm events results in erosion of cultivated slopes, bottomlands, and streambanks, and contributes to sedimentation problems in the lake.

The recommendations for enhancing Lake Lemon center on:

1. Reducing the generation of nonpoint sources of pollutants, particularly sediments and nutrients, from the watershed.

2. Reducing the delivery of nonpoint sources of pollutants to the lake.

3. Controlling shoreline erosion.

4. Managing the extensive growths of rooted macrophytes, particularly Eurasian water milfoil.

6.2 AGRICULTURAL BEST MANAGEMENT PRACTICES

The AGNPS modeling identified several areas within Lake Lemon's watershed that have a high potential for generating sediment and nutrient nonpoint source pollution. The implementation of agricultural BMPs should be encouraged in cases where field checks confirm the presence of potential NPS pollution. These BMPs are reviewed in Section 5.1. The local Soil Conservation Service (SCS) and Soil and Water Conservation District (SWCD) representatives are valuable sources of information and assistance. Assistance to implement site-specific BMPs should be requested from these agencies.

In particular, the current SCS policy promoting conservation tillage options should be promoted in Lake Lemon's watershed, especially on bottomlands. Likewise, the maintenance of vegetated streambank buffer (filter) strips should be encouraged throughout the watershed. Streambank filter strips reduce runoff velocity which allows for greater sediment and nutrient retention, and increases infiltration which decreases the runoff volume reaching the stream. With less runoff reaching the stream, peak discharge and the resulting erosive action of the discharge on streambanks is reduced. The Classified Filter Strips Act (HEA 1604), which was passed by the Indiana General Assembly in 1991, provides incentives to landowners who establish vegetative filter strips adjacent to ditches, creeks, rivers, wetlands, or lakes. Tax abatements apply to qualified filter strips meeting the law's requirements. Again, the county SWCD can provide local assistance and information.

6.3 FORESTRY BEST MANAGEMENT PRACTICES

Although large-scale timber harvesting is not presently occuring in Lake Lemon's watershed, the large percentage of forest land could make timber harvesting more important in the future. The steep slopes throughout the watershed make timber harvesting, even small operations, potentially serious sources of runoff and erosion. The development of timber resources in the watershed require careful planning and the implementation of the forestry best management practices described in Section 5.2.

6.4 URBAN BEST MANAGEMENT PRACTICES

Urban concerns identified during this and the earlier Phase I study include: construction site erosion, poorly operating on-site septic systems and fertilizer usage.

6.4.1 Construction Site Erosion Controls

Although there is not much construction activity along Lake Lemon's shoreline, there is significant undeveloped land with shoreline access that could be developed. Construction of homes and access roads on the steep shorelines slopes requires special precautions to prevent soil erosion. For example, erosion channels were visible on a home construction site along the northern shore of the lake during the summer and fall of 1990.

A comprehensive urban erosion control ordinance should be implemented around the lake to control erosion from construction activities. A procedure used by other Indiana communities is to appoint an Erosion Control Task Force to investigate the problem, identify options, and make recommendations. The task force should be composed of 6 to 8 individuals representing a broad range of experience in this area; for example, an engineer, a planner, a builder, a geologist, etc. Use the manuals entitled, *A Model Ordinance for Erosion Control on Sites with Land Disturbing Activities* (HERPICC, 1989) and *Urban Development Planning Guide* (HHRCDC, 1985) as resources. The county extension agent and the local SCS representative will also be important resources.

6.4.2 On-Site Septic System Management

While new regulations passed by the Monroe County Health Department provide significant restrictions on new on-site septic systems in Lake Lemon's watershed (the County regulations are more stringent than State regulations), existing systems and new systems in the Brown County portion of the watershed are exempt. The Brown County Health Department is examining the new Monroe County regulations and we encourage their adoption in Brown County as well.

The Phase I Study identified septic system contamination in the Chitwood Addition area at the southeast end on Lake Lemon and along lower Beanblossom Creek. Both of these areas are in Brown County. Standard procedures in the health department are to respond to complaints but not to conduct routine monitoring. However, in this case, we recommend that special monitoring be conducted by the Brown County Health Department in the channels of the Chitwood Addition and lower Beanblossom Creek to further assess the problem and to identify specific sources of contamination. Identified problem areas must then be corrected. The status of Lake Lemon as a back-up drinking water supply and the health of the residents along the water in these two identified areas requires that these additional efforts be made.

6.4.3 Fertilizer Management

The use of lawn fertilizers along lakeshore property should be carefully controlled. As discussed previously (Section 5.2.3), this can be an important source of nutrient loading to lakes. Public education through prepared brochures, newspaper articles, etc. should be sufficient. Enforcement may be necessary for persistent violators.

6.5 SHORELINE EROSION CONTROLS

Shoreline erosion is an active process on some shoreline areas of Lake Lemon (Figure 4-1). Eroded, unstabilized shoreline areas can be stabilized in most cases by regrading and revegetating as described in Section 5.3. On steep banks and on points where wind-driven waves are most severe, structural controls such as rip rap may be needed. Non-flexible controls such as seawalls should be discouraged because they cause greater erosion of the littoral zone below the seawall and can erode shoreline areas adjacent to the seawall.

6.6 STREAMBANK EROSION CONTROLS

Streambank erosion is a severe problem along lower Beanblossom and Plum creeks and a problem along nearly all other stream reaches in Lake Lemon's watershed. Section 5.3 describes several management techniques for eroded streambanks. The "willow post" technique is particularly effective on steep slopes and is relatively inexpensive. However, the resulting dense vegetation can make stream access difficult. Re-grading and re-vegetating is recommended on streambanks that are only up to 3-4 feet high. In many areas, simply leaving streambanks vegetated rather than cutting off the timber will help prevent erosion.

Because most of the eroded streambanks are on private land, lack of incentive and financial ability on the landowner's part may limit implementation. Cost-sharing assistance is available through the T-by 2000 Lake Enhancement Program. The Lake Enhancement Program offers technical and financial assistance for streambank erosion control through design and construction projects and lake watershed land treatment projects. Cost-sharing rates with the Lake Watershed Land Treatment Program are up to 80% State and 20% landowner. Lake Enhancement Program implementation grants are cost-shared at a 75:25 rate.

6.7 WETLANDS MANAGEMENT

Sedimentation basins are often used to trap suspended sediments prior to their discharge into receiving waters. To trap particles 20 microns and larger in size, guidelines recommend that such basins be sized at 0.2 percent of the watershed draining through them (Pitt, 1989). To meet this requirement, a sedimentation basin located at the mouth of Beanblossom Creek would require an area greater than 7,000 acres, more than five times the size of Lake Lemon itself. Clearly this is not feasible.

One alternative is to construct a series of smaller sedimentation basins in the upper watershed. Another may be to enhance the trapping efficiency of the wetland vegetation at the mouth of Beanblossom Creek, in combination with a sedimentation basin.

The 60+ acre wetland area at the mouth of Beanblossom Creek is composed of established, vegetated islands and deltas formed by sedimentation (Figure 6-1). The area is classified according to the National Wetlands Inventory as a combination of palustrine and lacustrine wetlands (Figure 6-2). Potential enhancement options include:

1. Constructing a low, vegetated berm to direct most of Beanblossom Creek's flow through the northern channel where existing meanders will reduce discharge velocity and allow sediment to fall out.

2. Construction of a small (6-7 acre) sedimentation basin to facilitate sediment trapping.

3. Construction of low, vegetated berms (filter strips) to decrease water velocity and to trap nutrients and additional sediments.

A conceptual design for this system is given in Figure 6-3. Sediments removed during construction of the sedimentation basin can be used to create the vegetated berms. A Section 404 Permit will be required from the Corps of Engineers to do this work. A permit from the Indiana Department of Natural Resources may also be required.

Other considerations must be given to accommodating the boats which travel between lower Beanblossom Creek and Lake Lemon. Wetlands enhancement will make boat travel difficult and unrestricted boat travel could jeopardize the functioning of the wetland system. At minimum, a "no wake" speed zone should be imposed through the system.

Dredging to provide a channel through the wetland system and through the existing delta may be required. At minimum, the existing channel from the mouth of Beanblossom Creek to the open water of Lake Lemon should be marked with buoys. By restricting boats to the marked channel, damage to wetland plants from motorboat prop wash can be minimized.

The Beanblossom Creek wetland is also an important waterfowl resting area and birdwatching site. Waterfowl species known to occur in the area include: pied-billed grebe, Canada goose, mallard, black duck, gadwall, wood

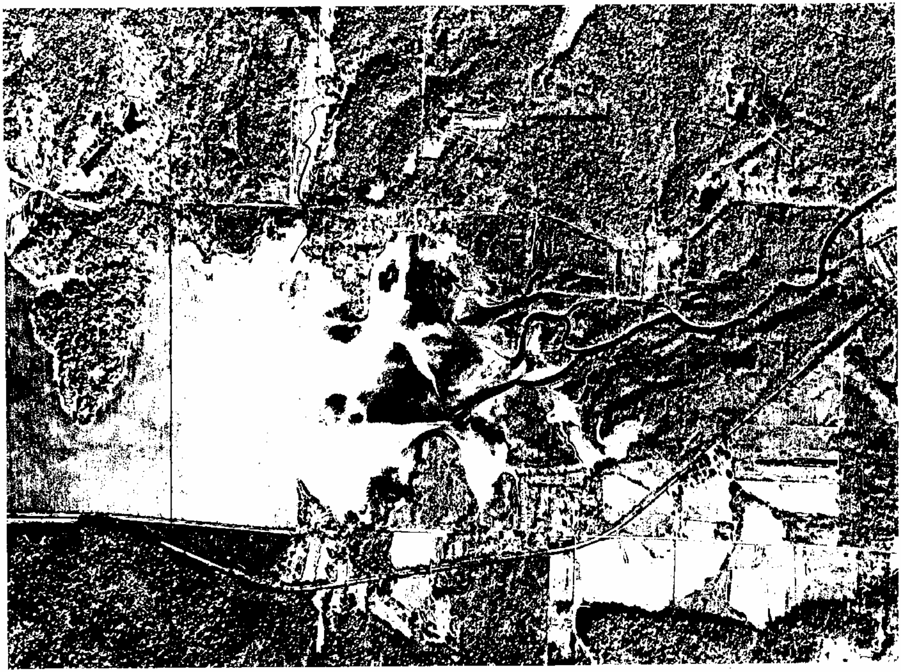
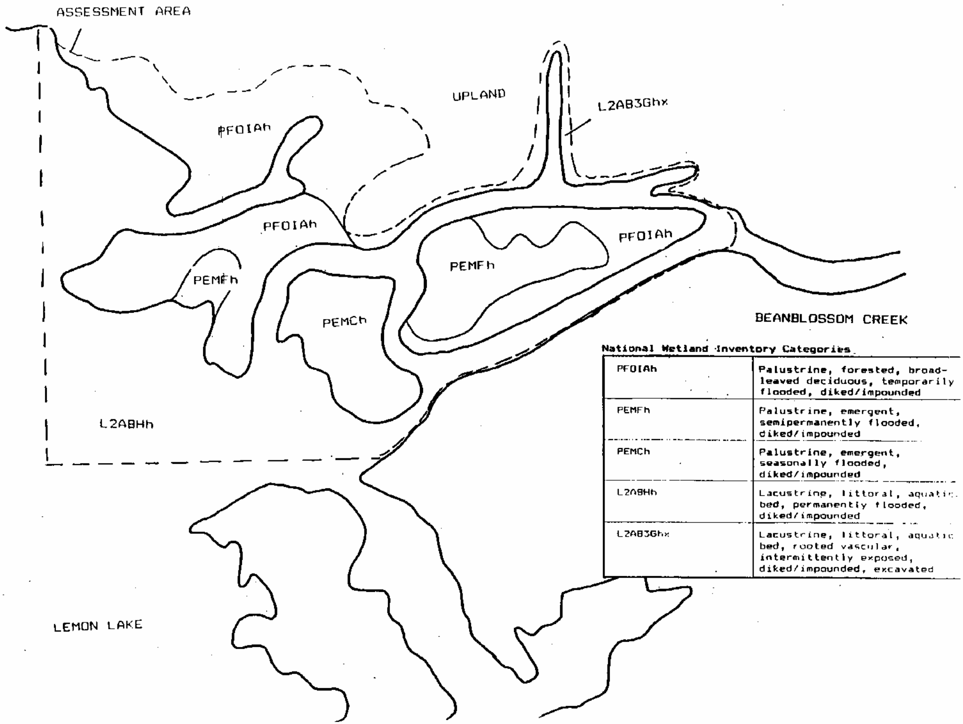


Figure 6-1. Aerial photo of Beanblossom Creek wetland at east end of Lake Lemon.



National Wetland Inventory Categories

PFOIAh	Palustrine, forested, broad-leaved deciduous, temporarily flooded, diked/impounded
PEMFh	Palustrine, emergent, semipermanently flooded, diked/impounded
PEMCh	Palustrine, emergent, seasonally flooded, diked/impounded
L2ABHh	Lacustrine, littoral, aquatic bed, permanently flooded, diked/impounded
L2AB3Ghx	Lacustrine, littoral, aquatic bed, rooted vascular, intermittently exposed, diked/impounded, excavated

Figure 6-2. National Wetlands Inventory designations for Beanblossom Creek wetland.

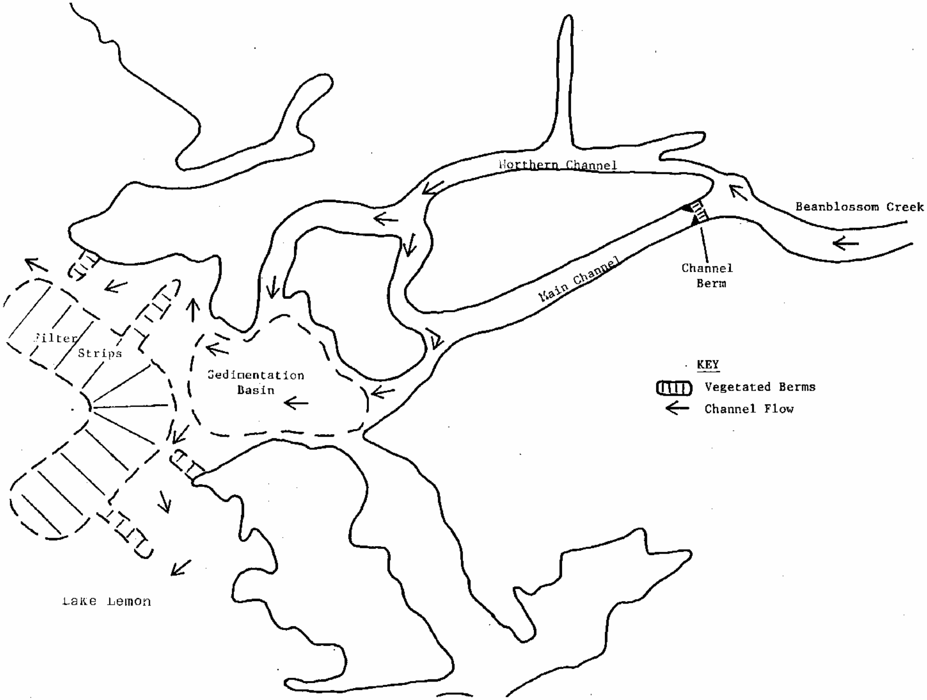


Figure 6-3. Conceptual plan for wetlands enhancement.

duck, lesser scaup, common merganser and American bittern (Whitehead, 1991). A number of rare waterfowl species are also sighted in the wetland annually. Bald eagles frequently utilize the wetland during migration periods and some eagles winter in the area. The motorboat speed and channel restrictions mentioned above will help protect this important waterfowl resource.

6.8 MACROPHYTE CONTROL

Macrophyte management at Lake lemon does not mean the elimination of all rooted aquatic plants. To the contrary, aquatic plants have many important benefits for water quality and other aquatic biota (see Section 5.3.2). Macrophyte management at Lake Lemon involves the control of just one nuisance species, Eurasian water milfoil (*Myriophyllum spicatum*). Control of milfoil can allow other, more beneficial macrophytes to replace it. For example, by harvesting the milfoil canopy, wild celery and other beneficial plants can receive enough light to grow up through the milfoil stumps. Establishing a diverse macrophyte population in Lake Lemon will improve waterfowl and fish habitat and can help stabilize shorelines from the erosive effects of waves.

Controlling the excessive growth and extensive coverage of Eurasian water milfoil remains the number one in-lake management need in Lake Lemon. The current policy of harvesting is effective but present capabilities can't treat all the areas needing harvesting. The City of Bloomington supplements harvesting with aquatic herbicide use in shallow areas that the harvester can't access and with winter drawdown. A long-term goal of the milfoil control program should be to discontinue use of aquatic herbicides at Lake Lemon, especially considering the lake's status as a back-up drinking water supply.

Winter drawdown remains the most cost-effective but under-utilized milfoil control technique for Lake Lemon. Its effective use can eliminate the need for chemical treatment in shallow areas and can enable residents to make shoreline repairs during drawdown. In addition, drawdown has fish management benefits by drawing small fish out of cover and making them more vulnerable to predation. This helps control the number of "stunted" fish.

Drawdown has been used previously at Lake Lemon. In years when winter drawdown could be successfully implemented, the need for additional macrophyte controls the following growing season was reduced. However, the drawdown capabilities at Lake Lemon are limited by a broken outlet gate mechanism and by the limited rate of discharge through the existing 42-inch outlet gate (see Section 8.3.2 in Phase I Report). At the peak discharge rate for this outlet (208 cfs), it would take 15 days to lower the lake level by 1.5 meters, providing no additional water flow into the lake from its tributaries, an extremely unlikely probability for December - February. A 1.5 meter drawdown would expose approximately 60 percent of the milfoil beds in the lake.

A top priority of any future lake management at Lake Lemon must include the repair to full operating condition of the existing gate and the increase in outlet discharge capacity. Additional discharge capacity could be achieved by adding an additional outlet gate to the dam or by providing supplemental pumping with hydraulic pumps and/or syphons. Adding an additional outlet gate would likely be most expensive but would increase discharge capabilities considerably more than would supplemental pumps.

Additional discharge should not increase downstream erosion or flooding. The outlet sluiceway is reinforced with rip-rap and has shown no damage at peak outlet discharge. The additional discharge from the outlet (208 cfs at current capacity) is but a small percentage of total downstream discharge. The annual peak one-day discharge for Beanblossom Creek below Lake Lemon usually exceeds 2,000 cfs and annual discharge exceeds 208 cfs for more than 200 days each year and usually exceeds 400 cfs for approximately 90 days each year (Horner, 1976).

6.9 RECOMMENDATIONS SUMMARY

Water quality in Lake Lemon can be enhanced by the implementation of the following:

1. Agricultural best management practices.
2. Forestry best management practices.
3. Streambank erosion controls.
4. Lakeshore erosion controls.
5. Septic system monitoring, maintenance and repair.
6. Construction of sedimentation basins.
7. Wetlands enhancement.
8. Continued macrophyte harvesting.
9. Outlet repairs and improvements to facilitate winter drawdown.

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